APPENDIX C

0905
Narrative for the Power Point Presentation, "Orange County Desalination Project: Marine Biological Analysis"

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Note to Users.

This notebook contains full page prints of the 36 Power Point figures used in my presentation on marine biological effects related to the reverse osmosis desalination at Huntington. Opposite each of the figures is a narrative, each page of which is numbered to correspond to the illustration. In some cases the narrative goes to a second page which is under the first. Some of the Power Point illustrations contain complete references. Other references are found on the last page of this document.

This work was prepared by me for the Poseidon Resources and is submitted to them on:

5 September, 2002

Jeffrey B. Graham

1. Title slide.
This shows the area of interest, the location of the AES Power Plant, and the position of its cooling water intake and discharge towers in relation to submarine topography and other coastal features. Purpose of this presentation is to interpret the salinity distribution models developed by Dr. Scott Jenkins with regard to the likely effect of increased salinity on organisms living in the vicinity of the discharge.

Orange County Desalination Project: Marine Biological Analysis

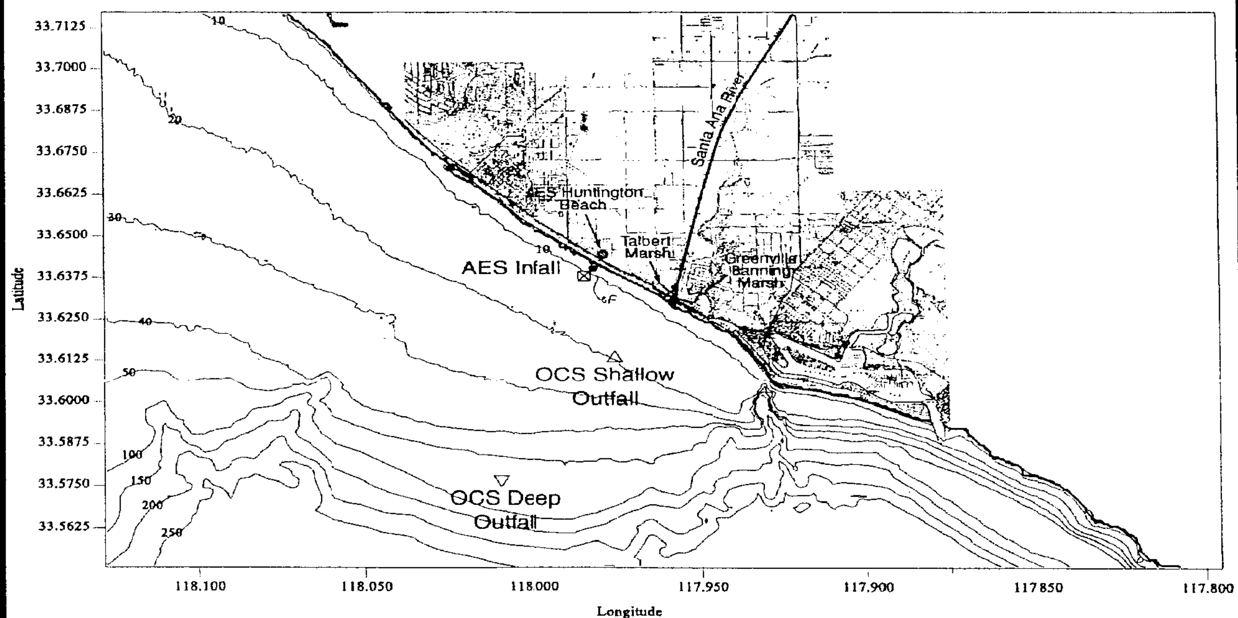

Figure 1.3. Location map for source-water modeling analysis due to fluxes from farfield sources.

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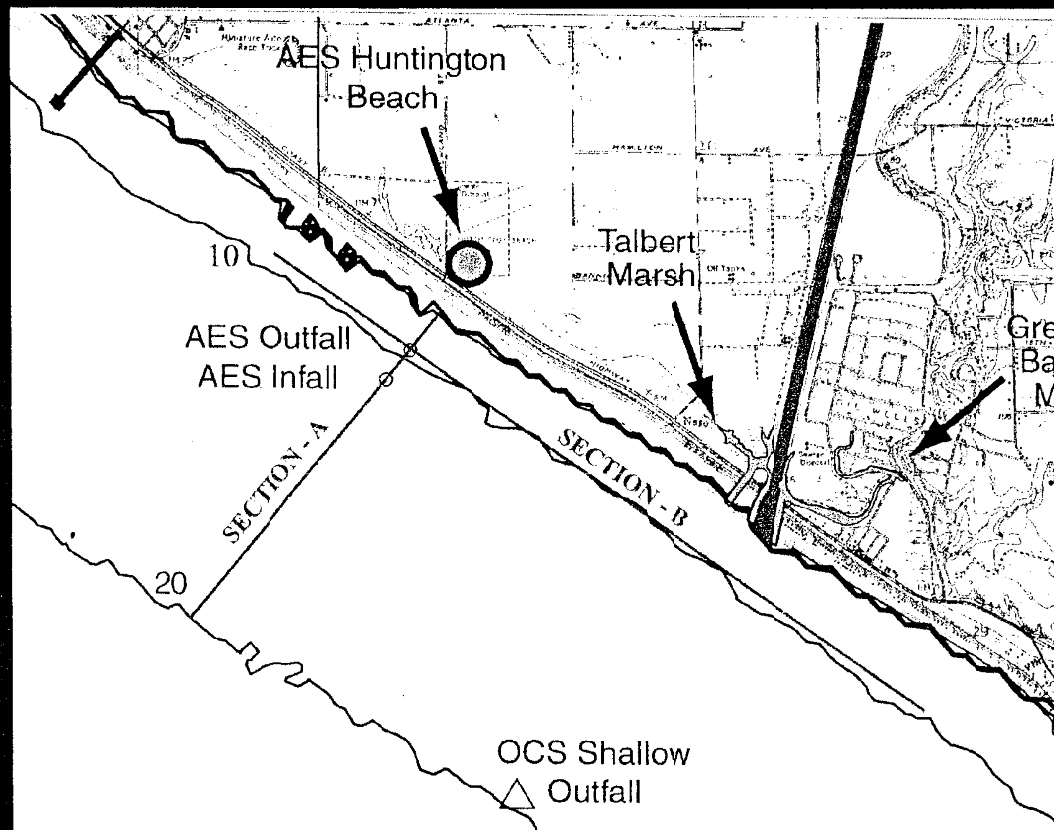
2. Map similar to 1 shows the cross-shore (A) and longshore (B) coordinates for the Jenkins and Wasyl analyses.

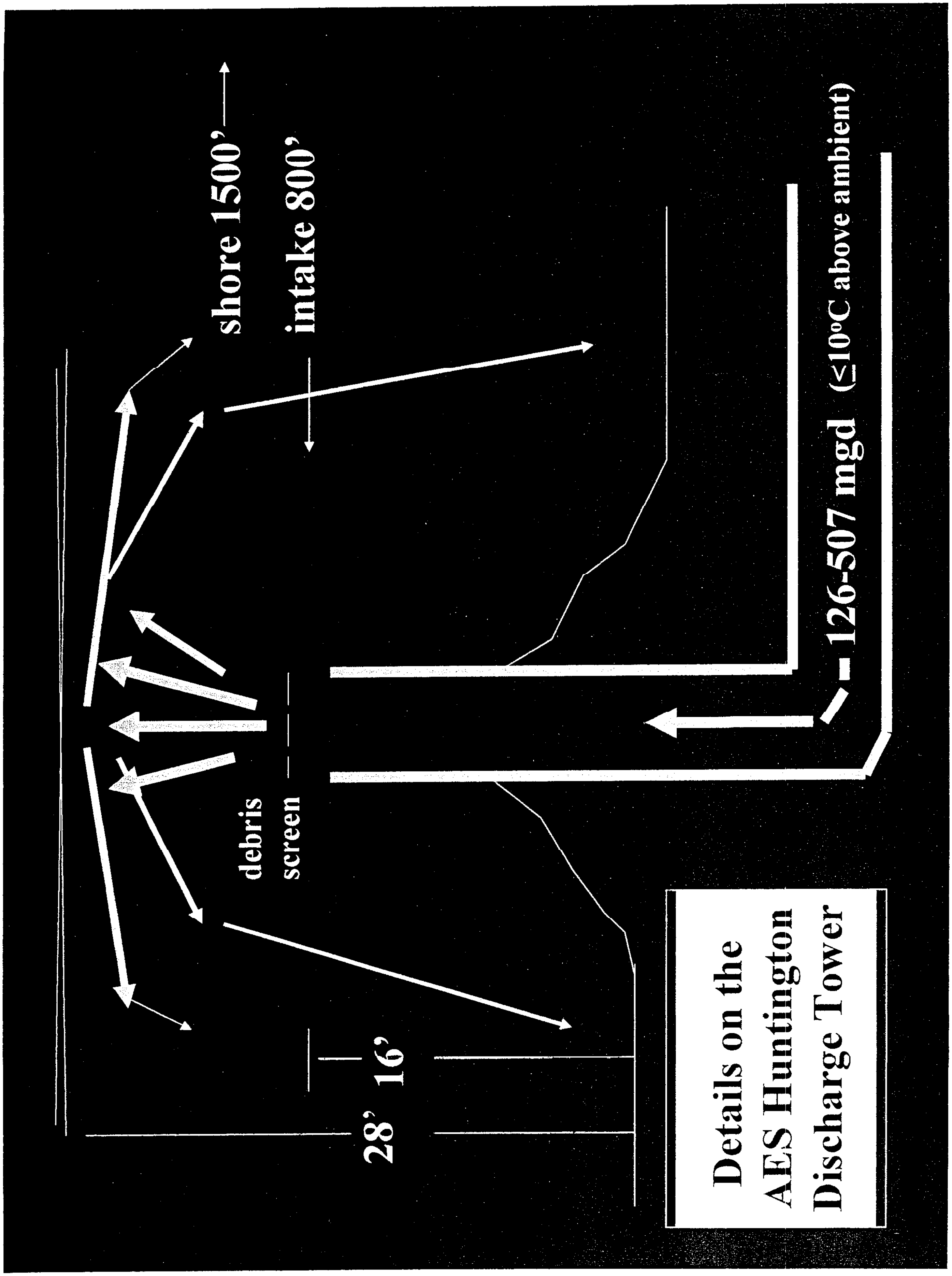
As you just heard from Scott Jenkins, modeling computational analyses were done to show how the warm, concentrated seawater discharge from combined power generating + reverse osmosis (RO) operations at the site would be distributed in the coastal waters. These analyses were resolved along two sections passing through the outfall: The cross-shore section (A) extends from the shore to the 20 m depth contour. The longshore section extends 4.5 km along a path parallel to the shore. The analyses reveal the fine-scale distribution pattern of the discharge salinity, indicate salinity level at any point within the discharge flow field (in both the longshore and cross-shore axes) and enable estimation of the salinity exposure times for swimming, drifting, and benthic organisms in the vicinity of the discharge.

A computerized analyses of the distribution pattern of warm, concentrated seawater has been done by S. Jenkins and J. Wasyl



3. Physical features of the AES Huntington Discharge Tower.

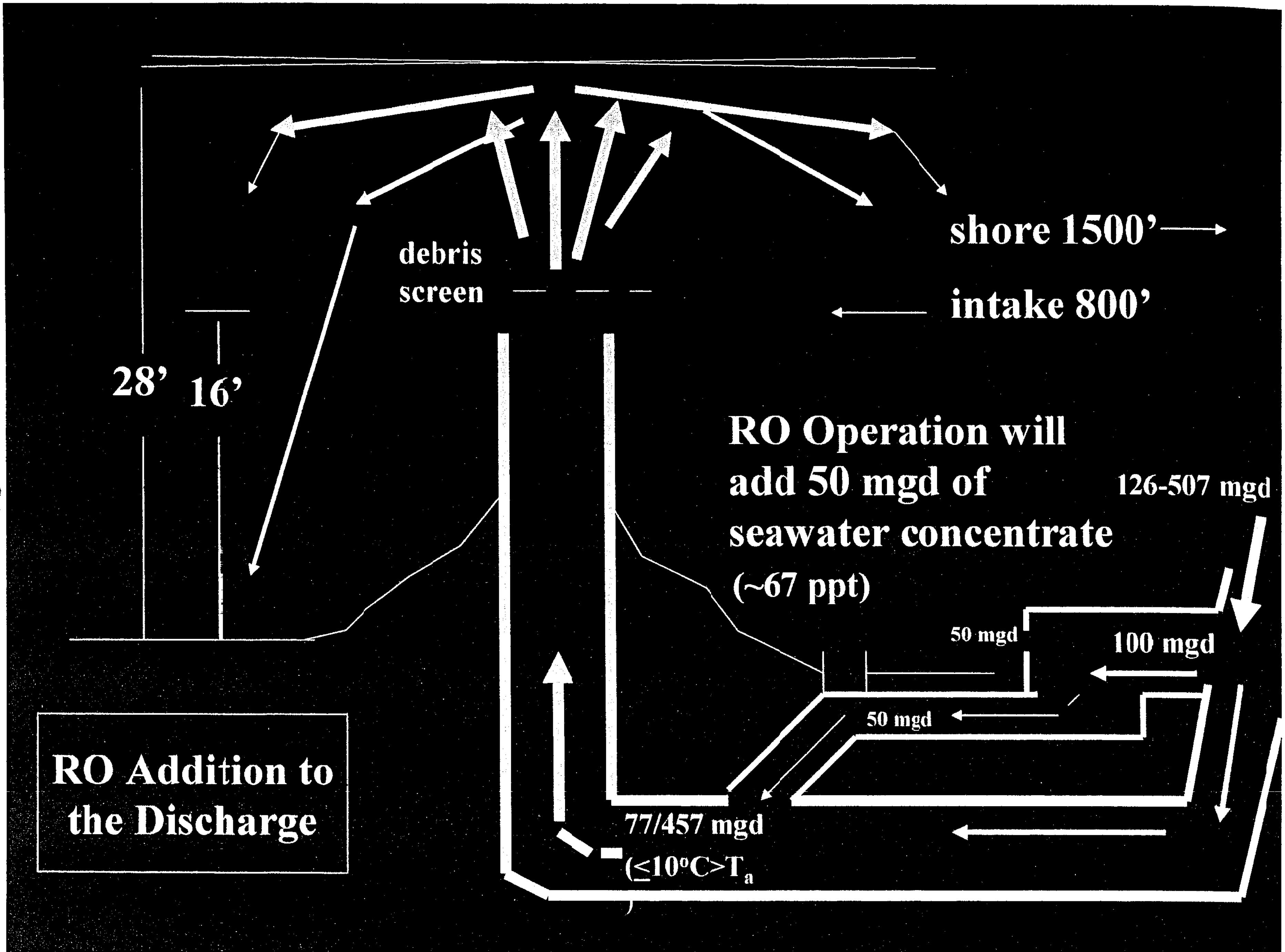
The discharge tower is located 460 m (1,500 ft) offshore. It is 240 m (800 ft) inshore of the water intake site. Water depth at the discharge site is 8-8.5 m (26-28 ft) and the tower extends 4.8 m (15.8 ft) above the ocean bottom. The power plant's water discharge rate is dependent upon the number of power generators on line and can vary between 127 to 507 million gallons per day (mgd). Permit regulations limit the temperature of discharge water to within 10°C (about 17°F) above ambient seawater temperature. The discharge pipe has a rectangular opening directed vertically upward through a debris screen toward the water surface. The momentum of the discharge water stream is sufficient to broach the water surface and establish a "surface boil" of water that expands 360 degrees outward from the region of surface contact. Because the warm discharge water is less dense, it remains mainly at the surface. However, because the combined RO + power plant cooling discharge stream modeled by Jenkins and Wasyl will be more saline, it will tend to sink as the boil loses momentum. As this happens the water mixes with and entrains ambient water, and vertical convective cells will form around the discharge tower. The distribution of this warm, concentrated seawater discharge and its eventual blending with ambient water was modeled by Dr. Jenkins in order to know evaluate its possible effects on the marine organisms living in the vicinity of the discharge.



Details on the
AES Huntington
Discharge Tower
shore 1500'
intake 800'
debris
screen
126-507 mgd (≤10°C above ambient)
28'
16'

4. The discharge function will change when the RO plant comes on line.

To produce 50 mgd of potable water, the RO plant will withdraw 100 mgd from the power-plant cooling flow. The RO byproduct, 50 mgd of approximately 2x concentrated seawater (67 ppt), will be injected into the cooling water discharge as it leaves the power plant. Considerable mixing of this seawater concentrate and the cooling water will occur before the combined flow is discharged into the ocean.



debris
screen
shore 1500'
intake 800'
28'
16'
RO Operation will
add 50 mgd of
seawater concentrate
(~67 ppt)
126-507 mgd
100 mgd
50 mgd
50 mgd
77/457 mgd
(≤10°C>T_a)
RO Addition to
the Discharge

5. Features of the Jenkins and Wasyl Salinity Profile Model.

Twenty years of coastal zone oceanographic and other data were used to model the combinations of coastal oceanographic and climatological features (e.g., wave height and periodicity, tidal range, wind speed, and current flow) affecting ocean mixing. The mixing level of the near-shore waters determines the rate at which the warm, concentrated seawater discharge stream will be blended with ambient ocean water. The 20 year record defines conditions for "average" mixing and conditions for rarely occurring periods of minimal mixing. These were used to model respectively, "Average" and "Worst Case" scenarios for RO and power plant discharge blending.

The "Average" scenario reflects first the infusion of the 50 mgd concentrated seawater RO outflow with the typically occurring power plant flow rate (PPFR). This mix is then discharged into an ocean having the "average level conditions affecting water mixing," as specified by a particular combination of tidal amplitude, wave height and periodicity, wind speed, determined from the 20 year records. The "Average" scenario was inititated for 30 days and the average salinity profile along transects A and B was solved.

The "Worst Case" scenario was based on the combination of a tranquil dry weather, with calm "La Nina" or summer ocean conditions and a minimal PPFR. These were initialized for 30 days straight and the resulting average salinity profile along A and B transects was solved. The "Worst Case" scenario thus combines factors that minimize ocean mixing (low wave height and periodicity, low (zero) wind velecity, low tidal amplitude, and low current flow) with factors maximizing the quantity of concentrated seawater in the discharge (a low total PPFR combined with the 50 mgd of RO byproduct). [In actuality, the combination of conditions constituting the "Worst case" are extremely rare for several reasons. First, the requisite summer ocean conditions have a very low probability of co-occurrence (1 week every 3-7 years). Also, these conditions have a low probability of persisting for as long as 30 days (models were perpetuated for this time to ensure numerical stability). Finally, the climate conditions associated with these periods (i.e., hot, windless summer days) would increase demand for electricity and result in a high rather than a minimal PPFR.]

Modeling the Discharge Salinity Profile

The Jenkins and Wasyl models solve the resultant RO salinity profile by modeling coastal oceanographic conditions affecting blending of the discharge and near shore water, including tidal amplitude, wave height and periodicity, wind velocity, and current pattern.

Over 20 years of coastal data enable determination of the "average" state of the near shore ocean and thus "average mixing conditions," and also define the combination of near shored conditions less favorable for ocean mixing which, although rare, do occur.

6. How power plant flow rate (PPFR) affects RO discharge salinity.

PPFR was combined with the oceanographic data to model discharge and ocean mixing and the resultant along-shore salinity profile. The greater the PPFR, the greater the "in-pipe" dilution of the RO byproduct before it reaches the ocean. The minimal operational PPFR is 126.7 and, with the RO operation, net PPFR is 76.7 mgd (126.7 - 100 +50 = 76.7 mgd). This net PPFR, which is only 1.53x the RO byproduct volume, was used to model the "Worst Case" scenario. The PPFR at the "Average" plant operating level, 253 mgd, was used to model the "Average" scenario (net average PPFR = 253-100+50 = 203 mgd).

Power Plant Flow Rate (PPFR), the daily volume of cooling water, is also important. This flow is the source for the RO plant and recipient of the RO plant's byproduct.

PPFR (mgd)	RO flow (mgd) intake	Total Discharge byproduct	Total discharge (mgd)	"In pipe" dilution factor+
*2 pumps @ 126.7	100	50	76.7	1.53
**4 pumps @ 253.4	100	50	203.4	4.07
maximum 507	100	50	457	9.14

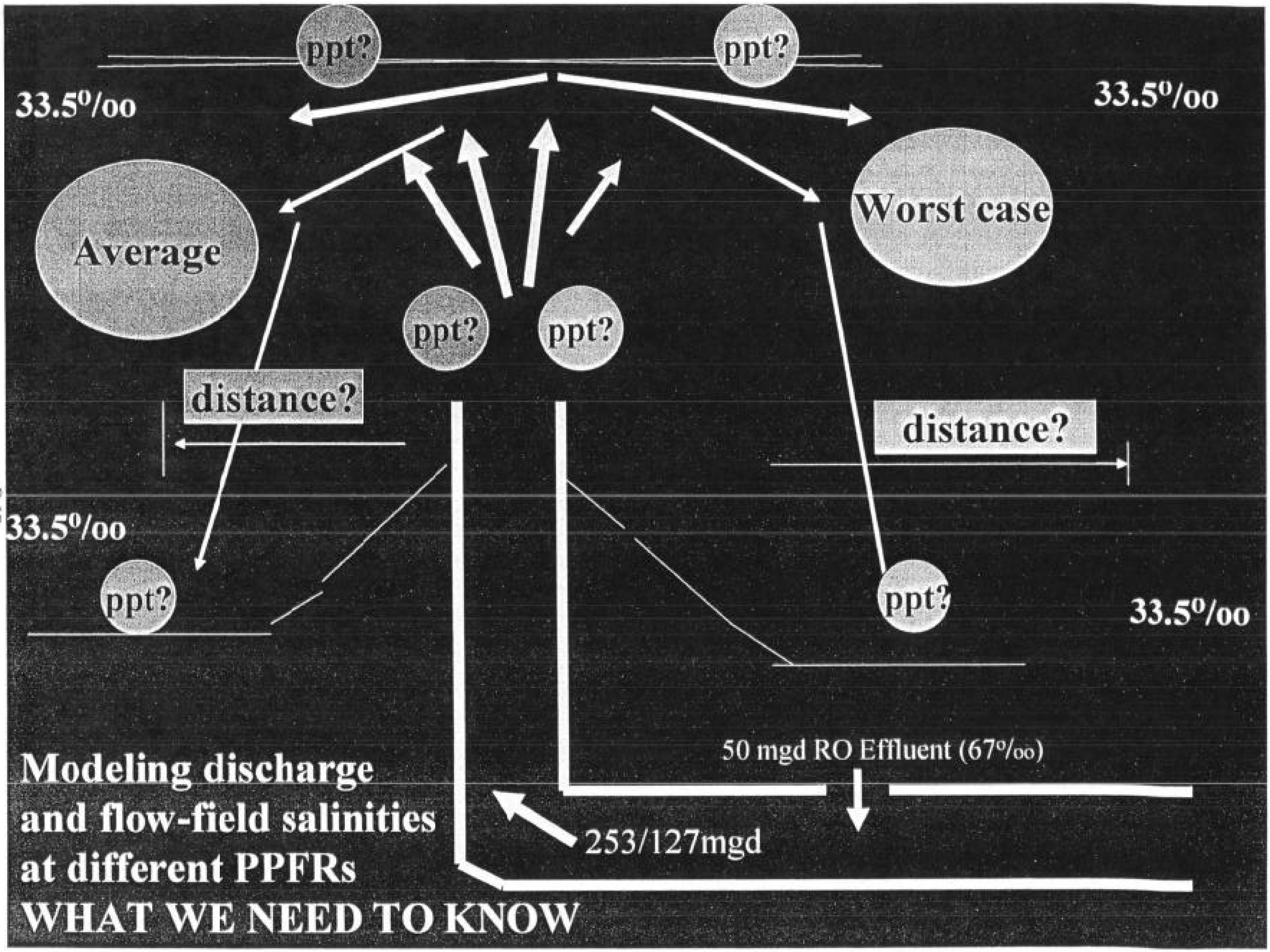
* used for "Worst Case" Model

** used for "Average Case Model"

+Ratio of total discharge volume to RO byproduct volume; the greater the ratio, the greater the amount of "in-pipe" salinity dilution before the discharge reaches the ocean

7. What questions about the salinity profile do the models address?

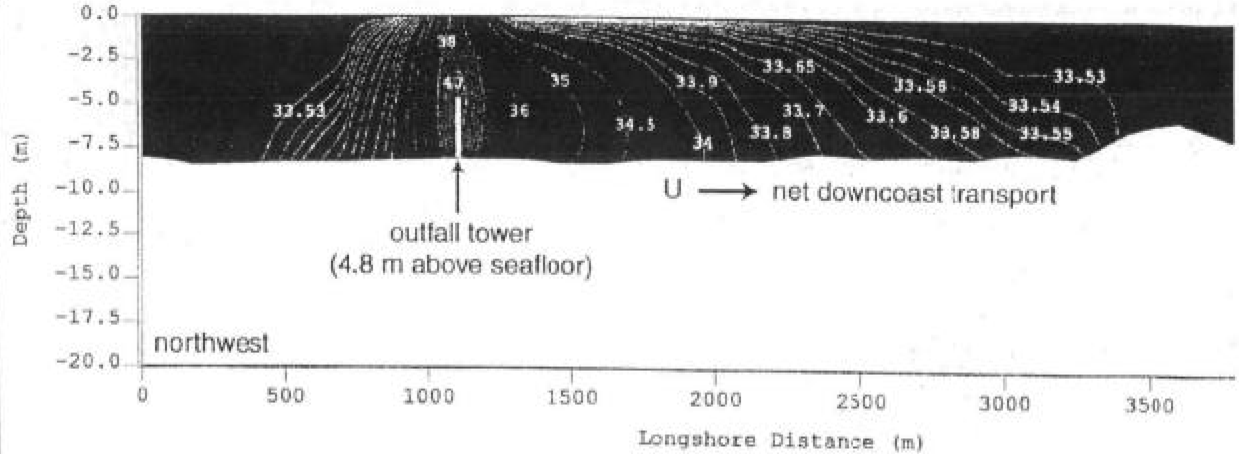
What will salinities be near the discharge and in the waters surrounding it? In what directions will the discharge plume go? How will salinity profiles change over distance? Will surface and bottom waters differ in salinity? What magnitudes of salinity change will organisms experience and for how long?


ppt?
ppt?
33.5‰
33.5‰
Average
Worst case
ppt?
ppt?
distance?
distance?
33.5‰
ppt?
ppt?
33.5‰
50 mgd RO Effluent (67‰)
Modeling discharge
and flow-field salinities
at different PPFRs
WHAT WE NEED TO KNOW
253/127mgd

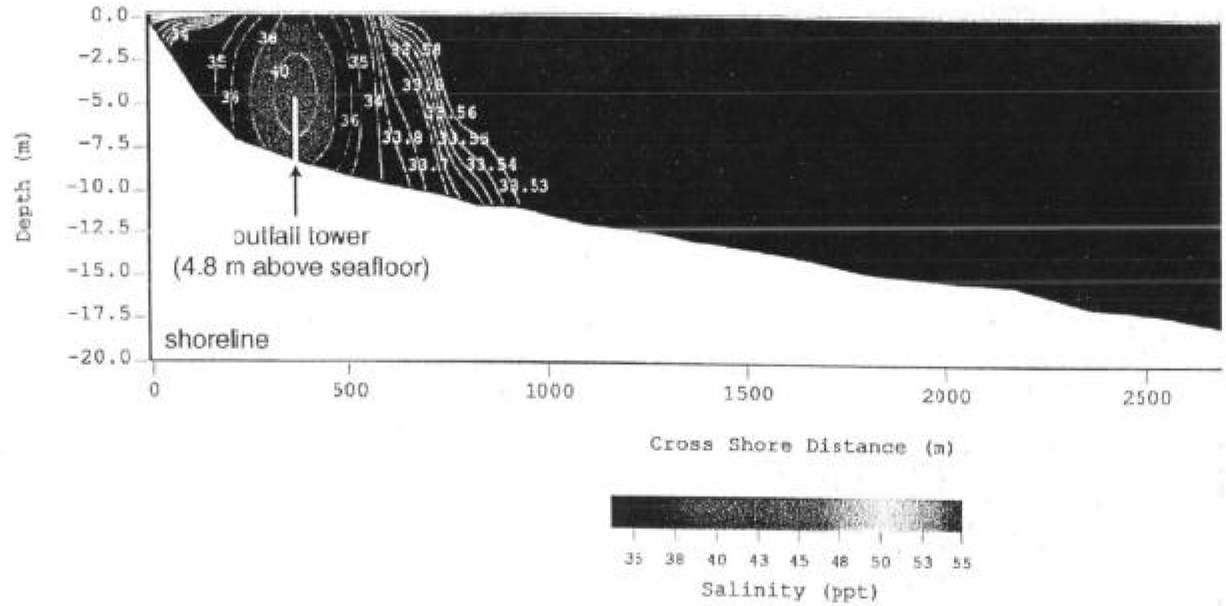
8. Average Case: Cross- and longshore salinity profiles.

These show the salinity profile that would prevail over a 30 day period in which the RO operates at 50 mgd, net PPFR is 203 mgd, and average ocean mixing conditions prevail. Conditions favoring the "Average" scenario would prevail about 50 percent of the time. The average salinity of the ocean water off Huntington Beach is 33.5 parts per thousand (ppt). The models show that the core area of elevated salinity ($\geq$40 ppt) remains within 50-100 m (164-328 ft) of the discharge site. The highest core salinity is 41 ppt and on the edge of the outer core salinity is 36 ppt. Because denser water sinks, salinities are greater at depth than on the surface, however, complete blending of the discharge water occurs within about 250-400 m (800-1300 ft) of the discharge. The longshore salinity profile shows downcoast movement with the direction of the net (24 h) current flow. The region of highest salinity ($\geq$40 ppt), which extends further at depth, is confined to within about 30 m (100 ft) of the discharge. The longshore distribution of the salt wedge persists for a long distance, but the salinity difference between the wedge and ambient water is very small. The downcoast distance to the point of complete water blending is about 1900 m (6200 ft) at depth, and about 900 m (3000 ft) at the surface. Note also that there are inner and outer salinity cores and a salt wedge.

Longshore salinity profile, Average Case



Cross-shore salinity profile, Average Case

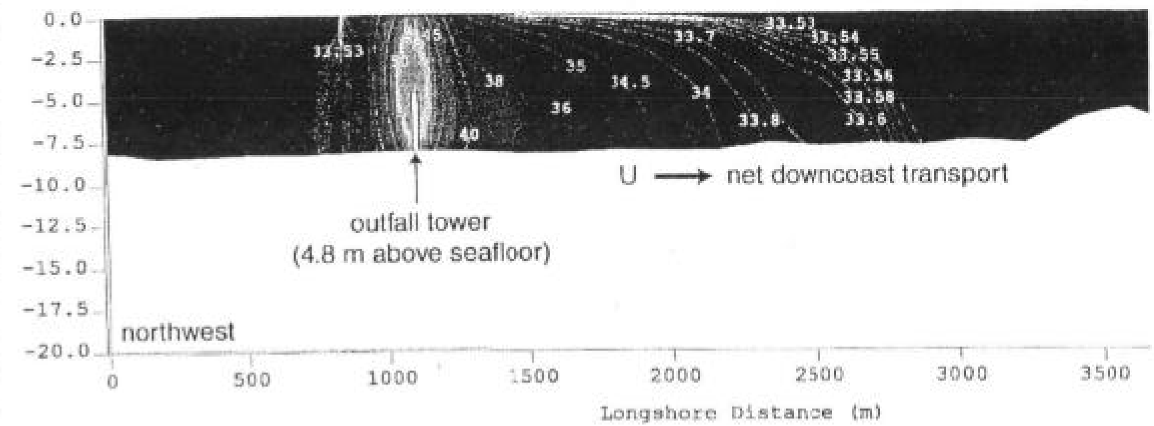


(Major features are inner and outer cores and the salt wedge)

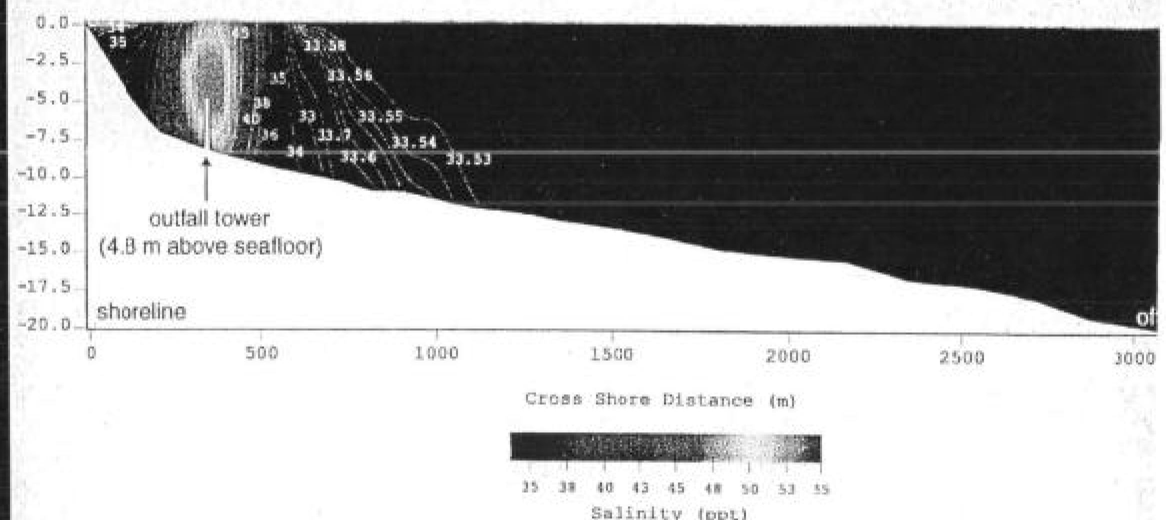
9. Worst Case: Cross- and longshore salinity profiles.

The Jenkins and Wasyl "Worst Case" scenario sets RO facility operation at 50 mgd, net PPFR at 77 mgd, and specifies a low state of ocean mixing. The probability of this set of conditions occurring is very low. Jenkins and Wasyl give the probability of these conditions persisting for a week within a three-year span at 0.0064. Over a seven year period, the probability of a week of these "Worst case" conditions is 0.0027. The images show a high-salinity area, composed of an inner core or jet with an upward momentum, and an outer core comprised of a large percentage of entrained water. The maximum salinity in the jet is 55 ppt, which, due to turbulent mixing, reduces to 50 ppt as water broaches the surface. The salinity of the entrained and sinking water of the outer core rapidly falls from 50 to 38 ppt. The inner core surrounds the discharge to a radius of about 40-50 m (131-160 ft). The outer core radius is asymmetric extending 300 m (984 ft) downshore, but only 150 m (490 ft) upshore. The salt wedge forms as the surface water loses momentum and begins to sink. The wedge spreads predominantly downslope [to about 800 m (2600 ft) offshore] and downstream about 1800 m (5900 ft). Its salinity ranges from 35 ppt down to only slightly greater than ambient (33.5 ppt).

Longshore salinity profile, Worst case.

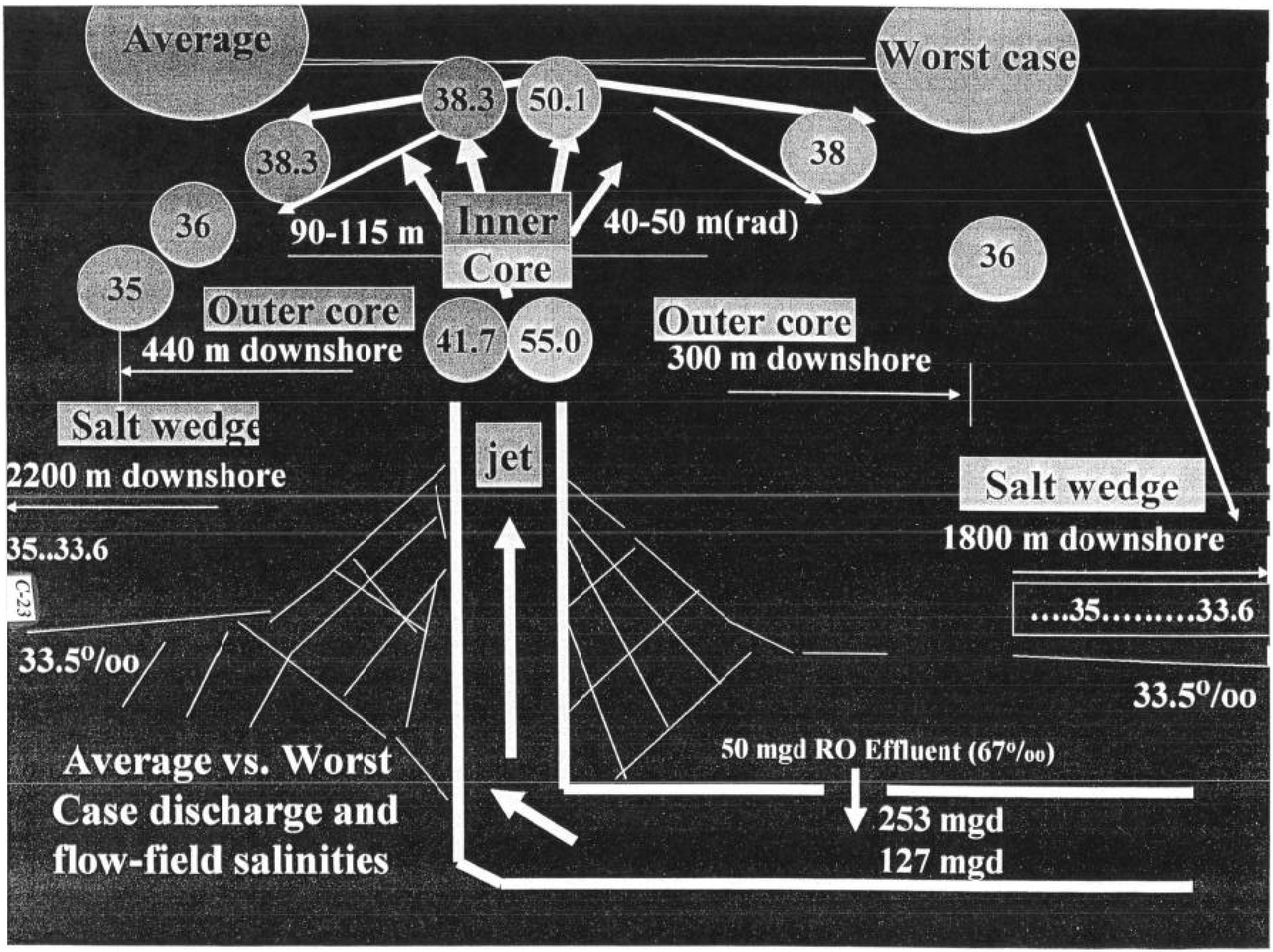


Cross-shore salinity profile, Worst case.



10. Quantitative comparison of the outfall patterns of the two scenarios.

In both the "Average" and "Worst Case" scenarios, the RO facility operates at 50 mgd, but the "Average" case net PPFR is about twice as large as that of the "Worst case" (203 vs 77 mgd). A greater net PPFR means more "in-pipe" dilution of the concentrated seawater, which, by lessening the water density gradient, lengthens blending time and distance.



Average
Worst case
38.3
50.1
38.3
38
36
90-115 m
Inner
Core
40-50 m(rad)
36
35
Outer core
440 m downshore
41.7
55.0
Outer core
300 m downshore
Salt wedge
jet
2200 m downshore
Salt wedge
35..33.6
1800 m downshore
C-23
....35.........33.6
33.5°/oo
33.5°/oo
50 mgd RO Effluent (67°/oo)
Average vs. Worst Case discharge and flow-field salinities
253 mgd
127 mgd

11. Tabular comparison of the two scenarios.

While the maximum salinity at the discharge is much less in the "Average" compared to the "Worst Case" scenario, differences in the outer cores and salt wedges for the two scenarios are not large and the downdrift persistence of the "Average" plume (which is less saline) is greater than the "Worse case."

Salinity Profile Comparisons: Average and Worst Case Models

	Average Case	Worst Case
RO (mgd)	50	50
PPFR (mgd)	253 (203)$^{+}$	127 (77)$^{+}$
Salinity (ppt)		
Ambient	33.5	33.5
Inner core		
Max	41.7	55.0
Nominal	38	50
Outer core (nominal)	36	38
Core radius (m*)		
Inner	90-115	40-50
Outer**	170-440	150-300
Salt wedge		
Nominal salinity (ppt)	33.7	35
Distance (m*)		
Offshore	570	800
Downdrift	2,200	1,800

$^{+}$NET FLOW

* distance values in meters (ft = 3.28 x m)

** core edge defined by 35 ppt salinity

12. Potential biological effects of a salinity increase?

By swimming or drifting into the discharge plume, or by living on the bottom near the discharge tower, marine organisms will come into contact with the warm, concentrated RO-power plant discharge.

Will they be able to tolerate its extremes?

Will the discharge disrupt the coastal community structure?

Will the area's biodiversity be altered?

Potential Biological Effects of a Salinity Increase

What organisms need to be considered?

1. Plankton and eggs drifting in water contacted by the discharge plume.
2. Fish, porpoise, seals, etc. that swim into the discharge plume.
3. Benthic (bottom) dwellers, i.e., crabs, snails, urchins, sand dollars, worms, shrimp, and some fish, that live in areas around the discharge where a permanent salinity increase will occur.

Questions about the extent of the effect.

How big is the salinity increase?

What is the area of the ocean affected?

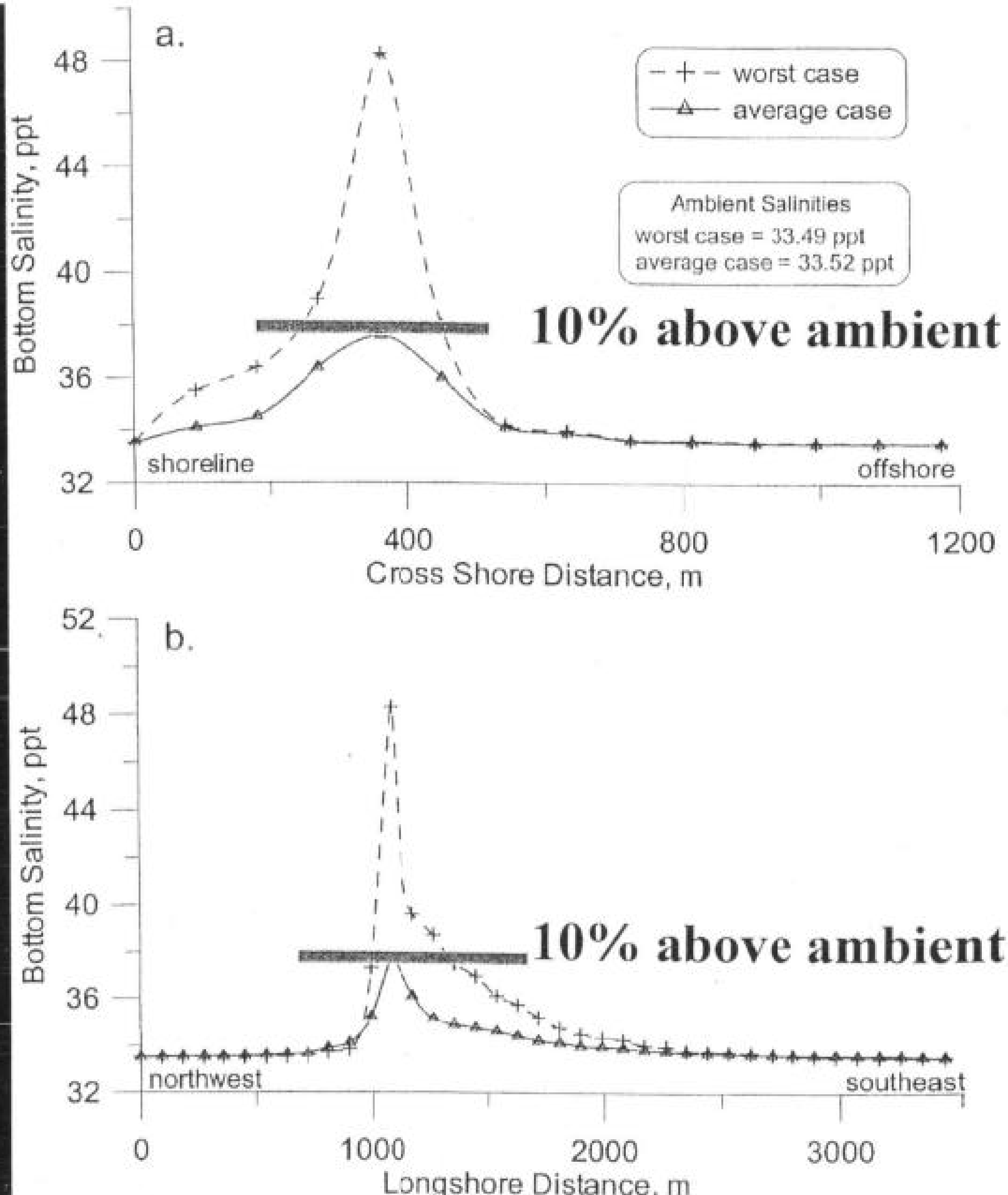
13. How will the salinity of the benthic habitat be affected?

Surveys of the macrofaunal assemblage in the sandy subtidal area offshore of the power plant show a core group of species throughout most of the area. The most common animals present are three species of polycheaete worms (*Diopatra, Owenia*, and a maldanids), hermit crabs, and the sand dollar (*Dendraster*).

Jenkins and Wasyl have also modeled the "Average" and "Worst case" predicted bottom salinities around the discharge. Cross- and longshore projections of this are shown (note the projections have different distance scales). For both scenarios, cross-shore salinity peaks near the approximate offshore position of the discharge [i.e., about 460 m (1500 ft) offshore]. For "Average" conditions the maximum bottom salinity is 38 ppt, however, the gradient is quickly dissipated and approaches ambient. Only a very small span of the bottom has a salinity of 37 ppt or greater (i.e., within 10% of the ambient salinity of 33.5 ppt). For the "Worst case," peak bottom salinity is 48.3 ppt. At the outer fringes of the inner core [approximate span is 150 m (492 ft)] salinity is 41 ppt. The cross-shore span of the bottom having a salinity of ≥37 ppt is 200 m (656 ft). The long-shore span of the bottom with this salinity is about 400 m (1312 ft). Beyond these distances bottom salinities quickly tend toward ambient.

Long- and cross-shore 30 day bottom salinities for average and worst case months.

(Most common benthic animals in the sandy offshore area include: sand dollars, annelid worms, and hermit crabs.)

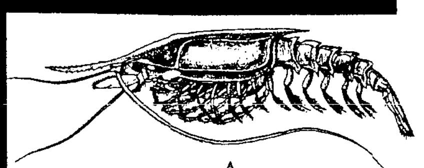


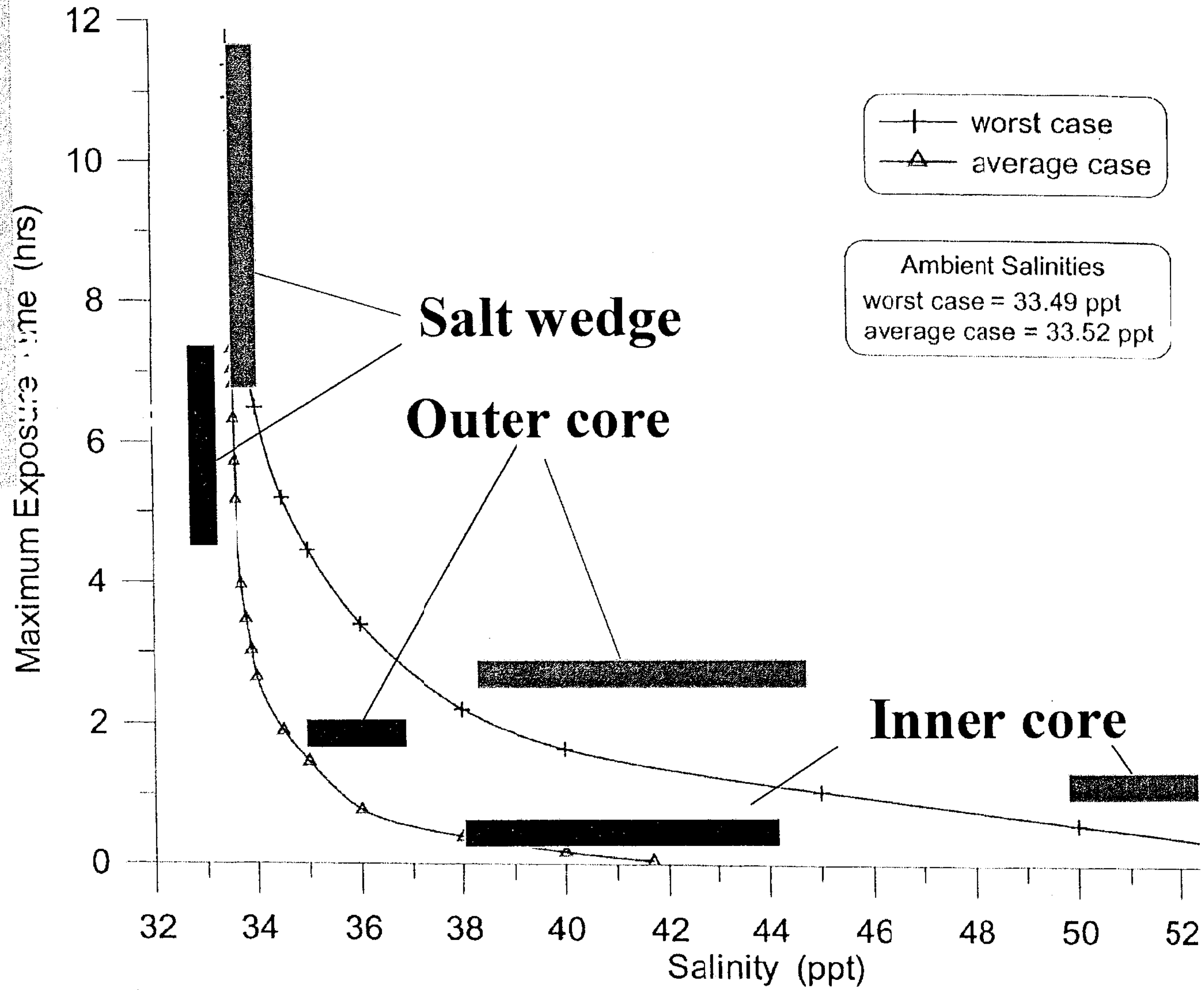
14. What would be the duration of salinity exposure for pelagic drifters?

The coastal-current-driven drift rate of nearly neutrally buoyant organisms such as zooplankton, eggs, and fish and invertebrate larvae, would bring them into contact with the increased salinity discharge. The path of their drift relative to discharge position would determine the level and duration of their exposure to the warm, increased salinity water. The water in which drifting organisms are entrained would mix with the discharge water and become warmer and saltier. As this water mass moved away from the discharge it would gradually return to ambient temperature and salinity, thus restoring normal conditions to the organisms within it. In the case of organisms drifting along a trajectory that would take them over the outfall, these would be swept away from this site by the outward momentum of the discharge plume. While organisms swept outward from the discharge jet would experience a marked rise in temperature and salinity, this would be very brief and none are likely to experience maximum-jet salinities and temperatures.

Jenkins and Wasyl modeled Lagrangian drift rates in the water mass around the outfall to predict the salinity exposure dose (i.e., level and duration) under both "Average" and "Worst case" conditions. Under "Average" conditions, exposure to the maximum inner core salinity of 40-42 ppt would be for no more than 10 min, and exposure at the inner core fringes (38 ppt) would be for only 23 min. An organism drifting into the outer core (36 ppt) would experience that salinity for 46 min; at the periphery of the outer core it would encounter 35 ppt for 1.5 h. Exposure times to salinities within the salt wedge range from 4.5 h (33.65 ppt) to 7.3 h (33.6 ppt). Under "Worst case" conditions, exposure to an inner core salinity of 53-55 ppt would be for 7 min while exposure at the inner core's periphery (50 ppt) would be for 35 min. Exposure to 45 ppt within the outer core would be for 1 h while, at the edge of the outer core, exposure to 38 ppt would be for 2.2 h. Within the salt wedge, exposures to a salinity of 34 ppt could be for up to 6.5 h while as long as 11.4 h could be spent in the salt wedge at salinities very near to ambient (33.5 ppt). **As will be shown subsequently, these salinity extremes and exposure times are all relatively small and well within the demonstrated tolerances of most marine organisms.**

Maximum exposure times of drifting organisms to elevated salinities under "average" and "worst case" conditions





15. How large an area of ocean is affected by "Average" and "Worst Case" scenarios?

The models also consider the area of the effect. Under the "Average" scenario, 7-8 acres of benthic and pelagic habitat around the discharge tower will experience a salinity increase of 10% or greater (i.e., 36.9 to 38.3 ppt). The benthic area experiencing a 1% or greater salinity (i.e., 33.8 to 36.9 ppt) is 130 acres, the pelagic area is 172 acres. Under the "Worst case," the benthic (16 acres) and pelagic (18 acres) areas that would experience a ≥10% salinity increase are twice as large; the pelagic acreage experiencing a ≥1% salinity under the "Worst Case" scenario is 14% greater than that under "Average" conditions, and the "Worst case" benthic area is greater by 35%.

Biological Effects of the RO Salinity Profile: The Area Exposed

[Reference Facts: Average ocean salinity ppt. 20 year range 31.3-34.4 ppt. A 10% change = 36.9 ppt. A 1% change = 33.8 ppt.]

Average Conditions (average ocean mixing and plant flow rates, > 50% probability of occurrence). How does salinity affect habitat?

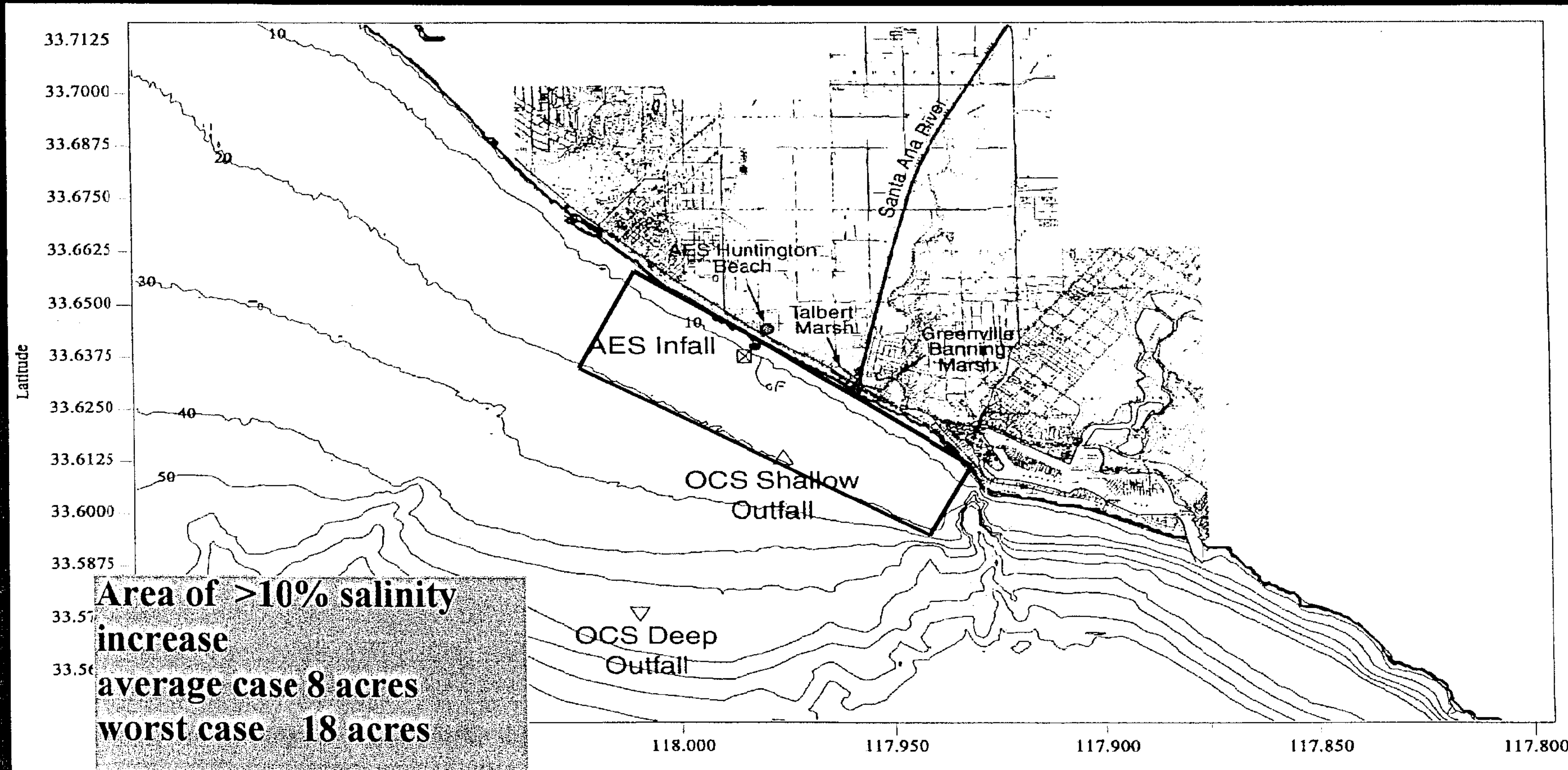
		Pelagic	Benthic
Acres of salinity increase of:	10%	8	7
	1%	130	172

Worst Case (low ocean mixing, low water flow, <u><<1% probability</u> of occurrence). How does salinity affect habitat?

		Pelagic	Benthic
Acres of salinity increase of:	10 %	18	16
	1%	151	263

16. Put this area in perspective by comparing it to a stretch of beach nearby.

Under "Average" conditions, seven acres of benthic habitat and eight acres of pelagic will receive a 10% salinity increase. Under "Worst case" conditions, 18 acres of pelagic and 16 acres of benthic habitat will experience a 10% salinity increase. Contrast these areas the area contained within the black lines on the map. These lines define the 1-20 m contour for the area extending upcoast from Balboa to Huntington State Beach (14th St.). The line-enclosed area is about 6000 acres.



Area affected by the increased salinity profile is quite small relative to similar habitat in the area.

Area enclosed by black lines = 6000 acres.

Area affected by the increased salinity profile is quite small relative to similar habitat in the area.

17. Compare it to the Southern California Bight.

At a minimum, the majority of species living near the Huntington discharge have a geographic distribution extending throughout the SCB. The approximate area of the SCB lying within a depth range of 1-20 m is about 440,000 acres. Thus, the areal effect of the combined power plant RO discharge is, in addition to being mild, is highly localized. While these area comparisons provide perspective, the intention in presenting them is to neither trivialize or "write-off" the potential biological impacts of the salinity discharge on the organisms living near the discharge site. The comparisons do nevertheless show that, relative to the vast expanse of the sand-dwelling marine community and the area within the SCB where this community occurs, the physical effects of the RO byproduct + power plant discharge at Huntington Beach are both slight and very localized.

Virtually all of the organisms living in the vicinity of the Huntington discharge have distributions that extend throughout the SCB

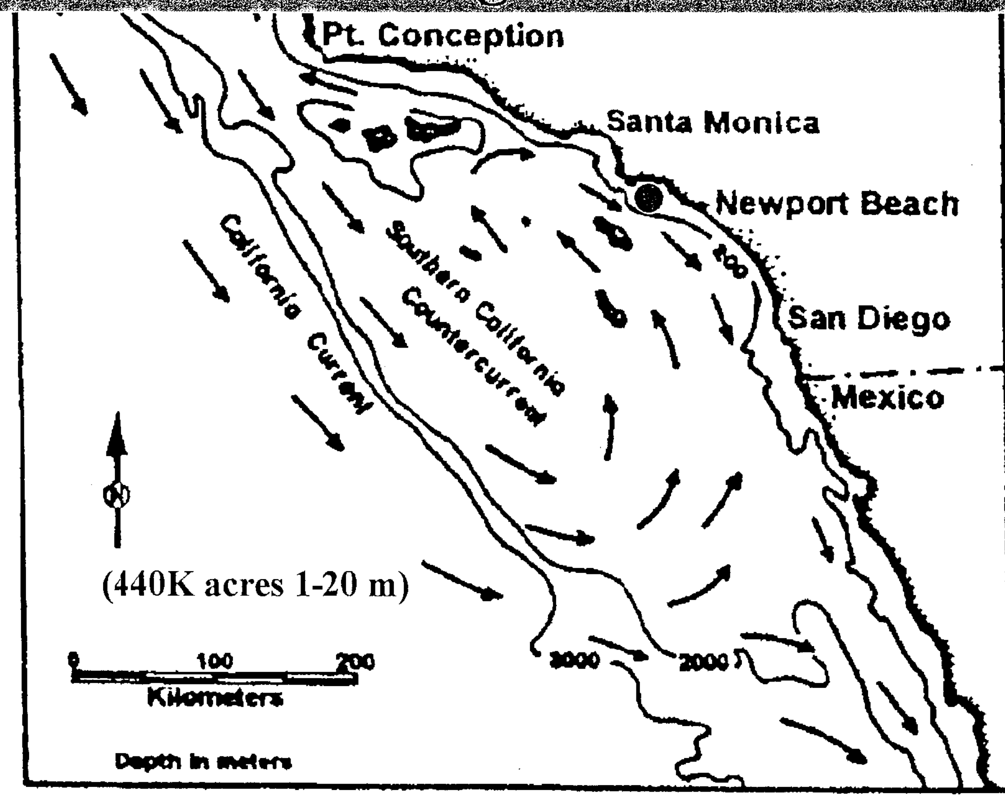
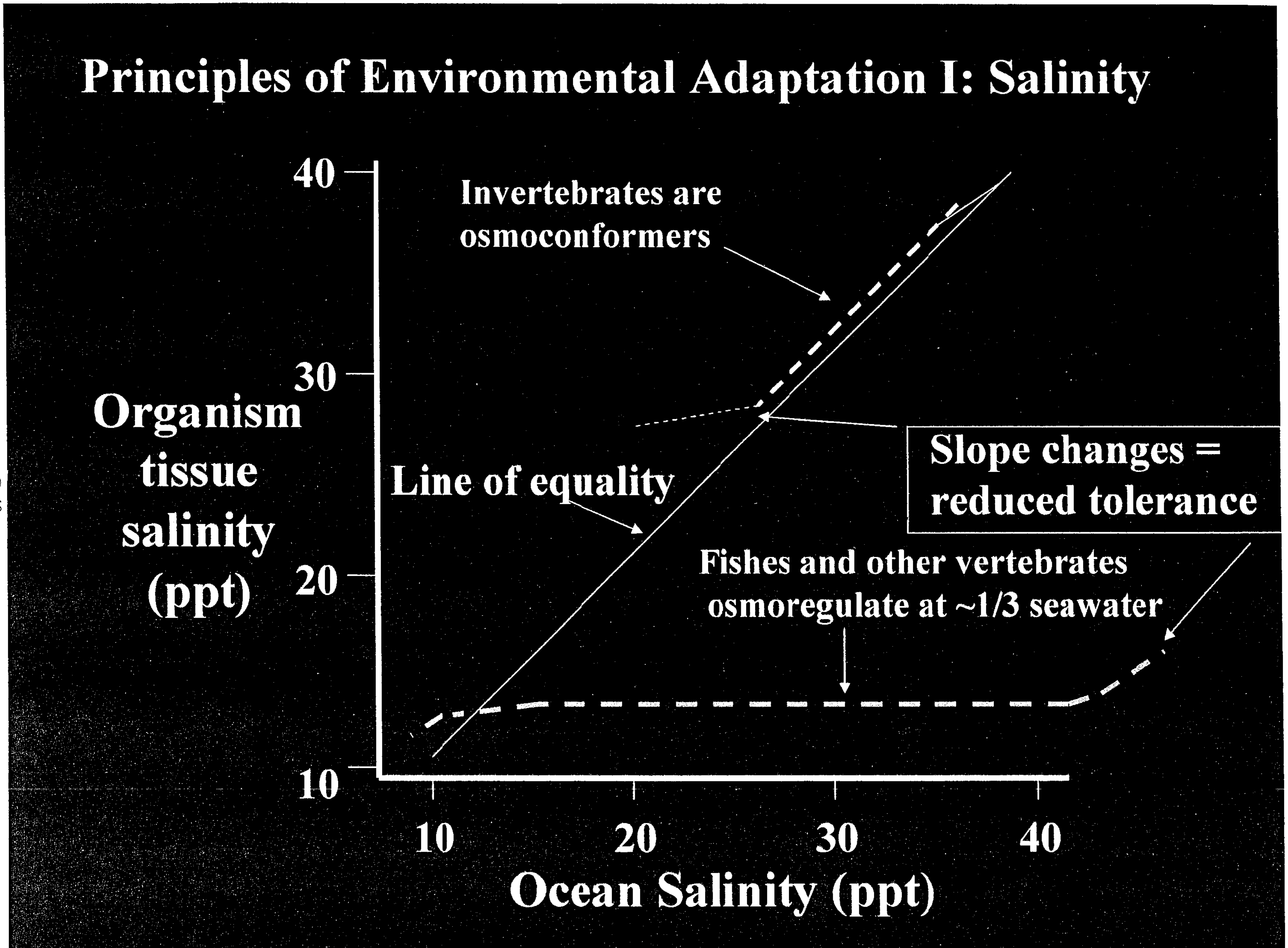


Figure 1. Surface circulation in the Southern California Bight (from Jones 1971). AES Huntington Beach L.L.C. generating station NPDES, 2000.

18. Principles of environmental adaptation I: Salinity.

This illustration continues to frame the biological questions in the context of how organisms make environmental adaptations. The ability to regulate salt level within body tissues is the key to salinity survival and tolerance. The capacity of organisms to control the levels of salt in their bodies is called osmoregulation, the central concepts of which are emphasized in several keys terms including, diffusion, hyperosmotic, hyposmotic, isosmotic, osmoconformity, and osmoregulation. Vertebrates and invertebrates have different osmoregulatory mechanisms. Salinity tolerance limits involve the inability to regulate salt levels under extreme conditions.

It is necessary to consider the osmoregulatory capacities of three different groups of organisms occurring at the Huntington discharge: Drifters such as eggs, larvae, and plankton will be carried by currents into the area and then remain within the flow field of the discharge water. Swimmers such as fishes, other vertebrates, and large invertebrates, may happen upon the higher salinity area. Benthic residents of the sandy bottom around the discharge tower will be permanently exposed to an increased salinity regime imposed by the outer core and salt wedge water. established at the base of the discharge tower. It is easiest to understand the effects in terms of a "salinity dose" (i.e., magnitude of the effect in combination with the duration of exposure to it).


Principles of Environmental Adaptation I: Salinity
40
30
20
10
Organism tissue salinity (ppt)
Invertebrates are osmoconformers
Line of equality
Slope changes = reduced tolerance
Fishes and other vertebrates osmoregulate at ~1/3 seawater
10
20
30
40
Ocean Salinity (ppt)

19. Principles of environmental adaptation II: Temperature.

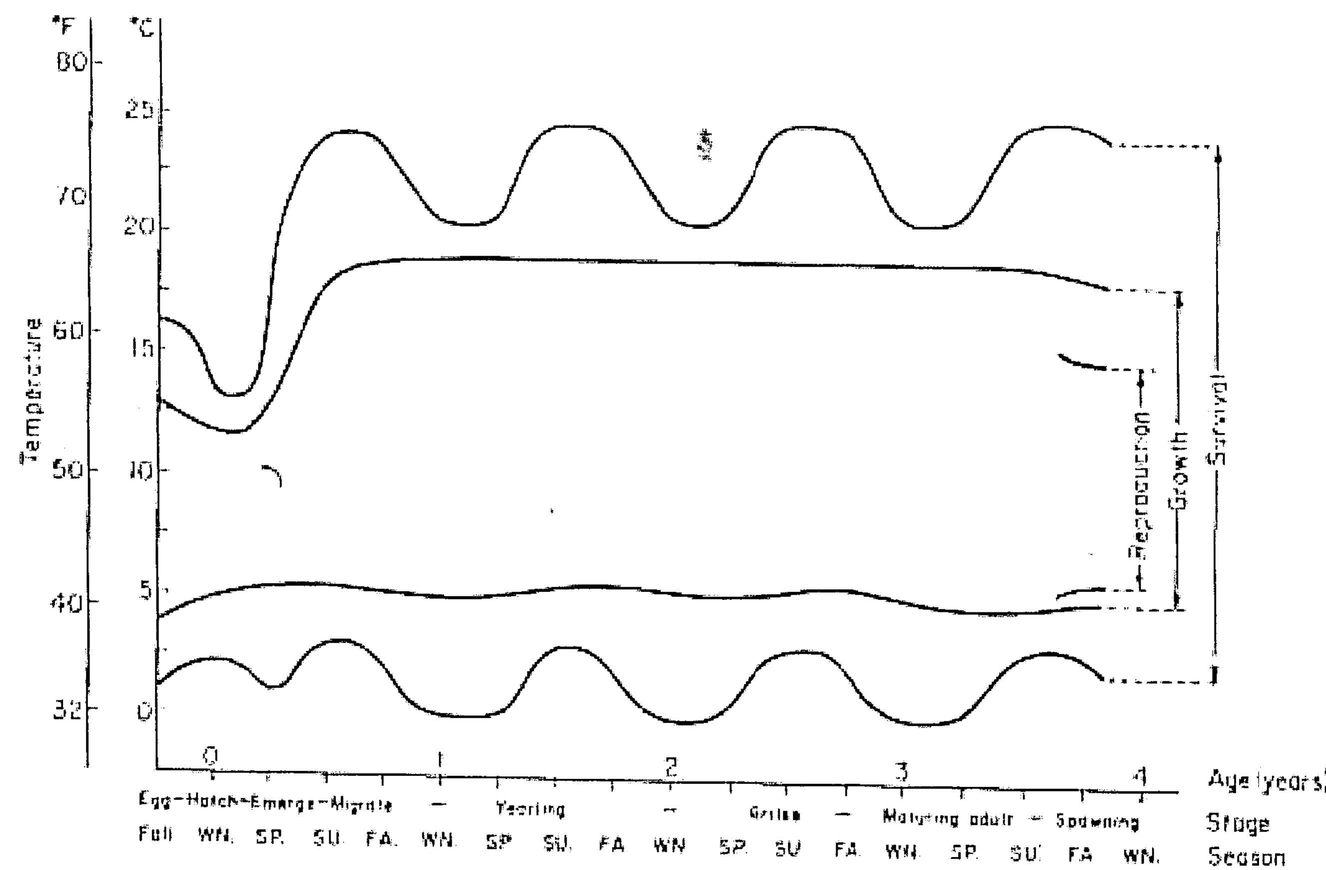
Although RO removes a percentage of plant heat from the effluent (i.e., the amount contained in 50 mgd of RO product), an elevated water temperature remains a feature of the discharge. Temperature is an important and well-studied environmental variable.

Every developmental stage of fishes and invertebrates is directly affected by temperature.

Organisms can adapt to local and seasonal temperature changes.

Salinity and temperature often have synergistic effects on organisms.

Principles of Environmental Adaptation II: Temperature



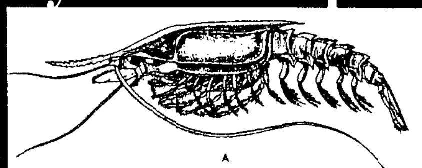
Representative thermal limits for different life processes of a salmon

20. Salinity tolerance tests determine the survival limits of a species.

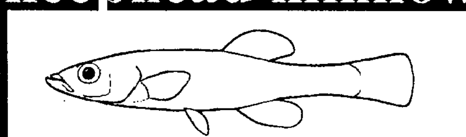
Whole effluent laboratory toxicity (WET) tests are applied to species living in areas where it is suspected that a discharge might have an effect on survival. These define the dose lethal to 50% of the test group, LC50; such data are shown for two fishes and a mysid shrimp.

Whole Effluent Toxicity (WET) salinity tests on marine animals (Pillard et al., 1999 Env. Tox. Chem. 18:430)

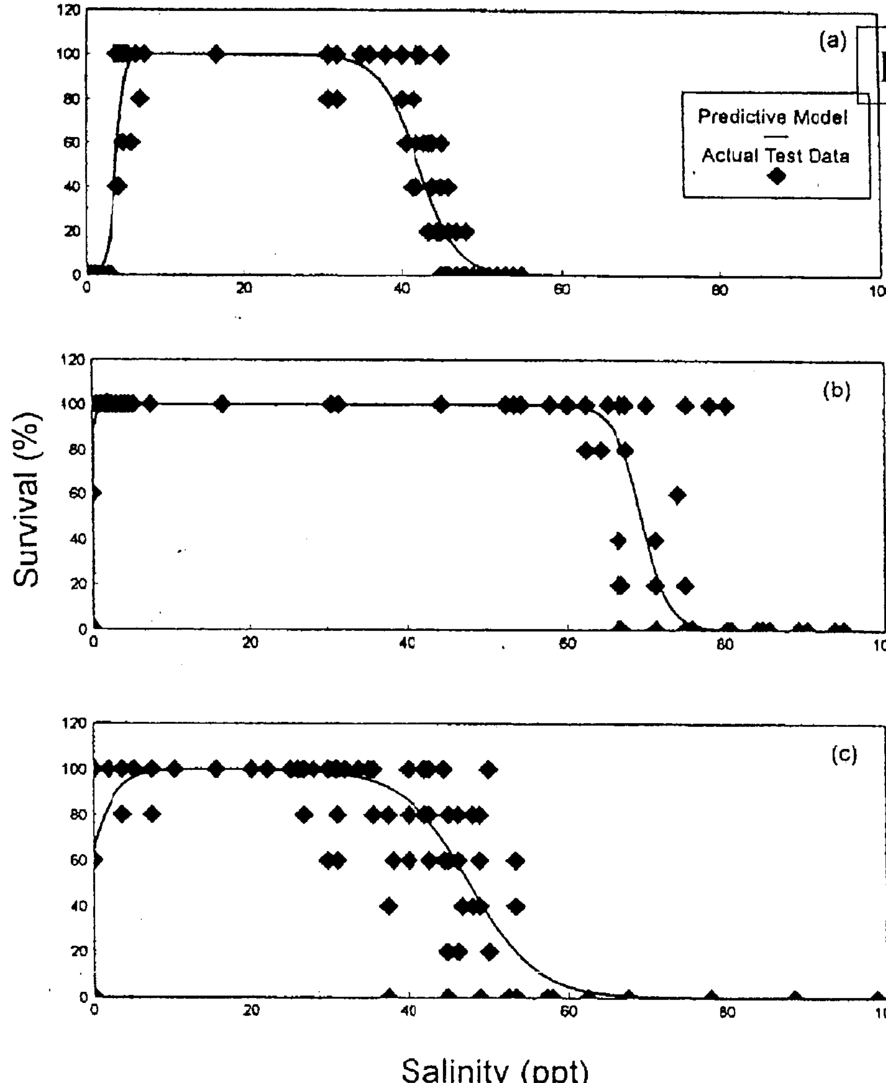
Mysidopsis
mysid shrimp



Cyprinodon
sheephead minnow



Menidia
silverside minnow

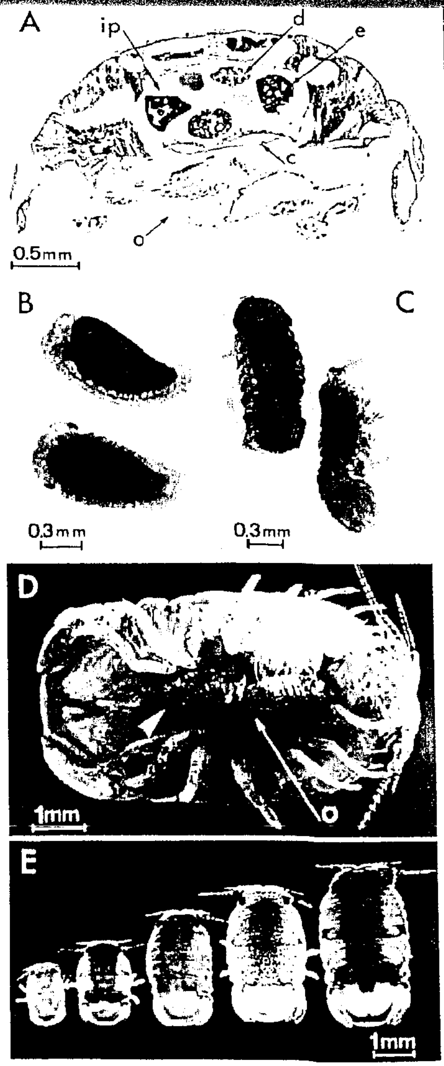


LC50
43
70
44

21. Salinity tolerance is different at different life stages and this must be taken into account. Data show that the upper salinity tolerance of the coastal marine isopod *Sphaeroma serratum* increases over stages I-V and adult. Note, all levels lethal for isopods are >55 ppt, which greatly exceeds predicted "Average" and "Worst Case" scenarios.

Salinity Tolerances of different aged isopods (*Sphaeroma*)

(Charmantier and Charmantier-Daures, 1994 Mar. Ecol. Prog. Ser. 114:93.)

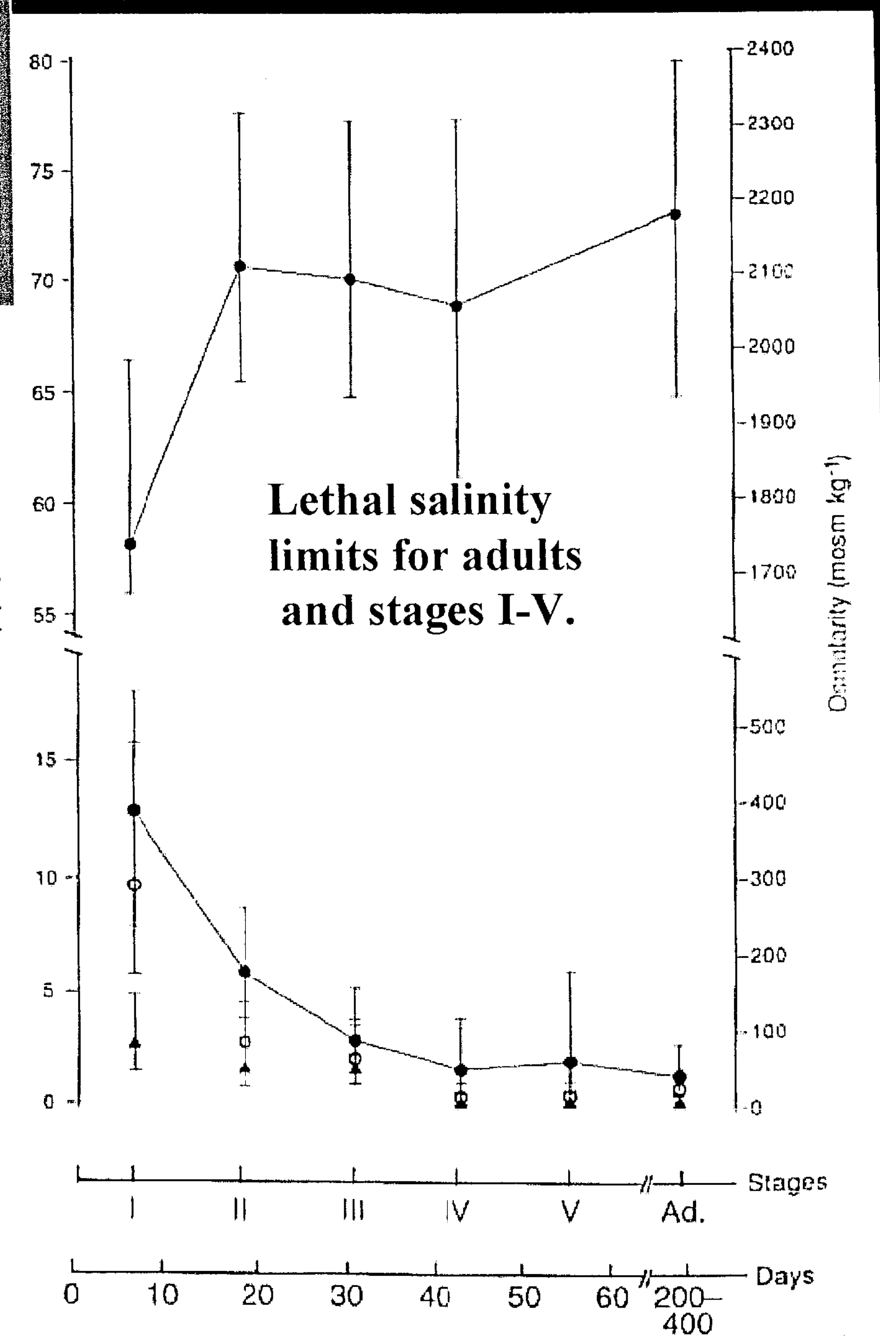


Mom's carry eggs and different aged embryos in brood pouch

Late embryos

Juvenile stage I

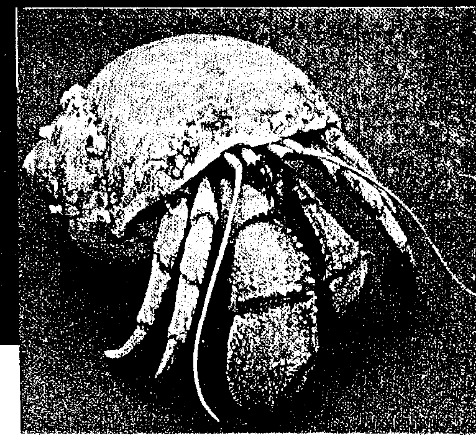
Stages I-V



22. Combined effects of temperature and salinity on the survival of different post metamorphic life stages of hermit crabs (*Pagurus*).

Graphs show metamorphic stage transitions. At 25°C and 25 ppt there is the longest survival, with a greater percentage of larvae completing metamorphosis to reach the C1 stage. Stage survival in extreme salinities exceeds time of exposure predicted for "Average" and "Worst Case" scenarios for the Huntington discharge.

Hermit crab (*Pagurus*) life stage survival in different salinities and temperatures (Blaszkowski & Moreira, 1986, J. Exp. Mar. Biol.Ecol. 103:77)



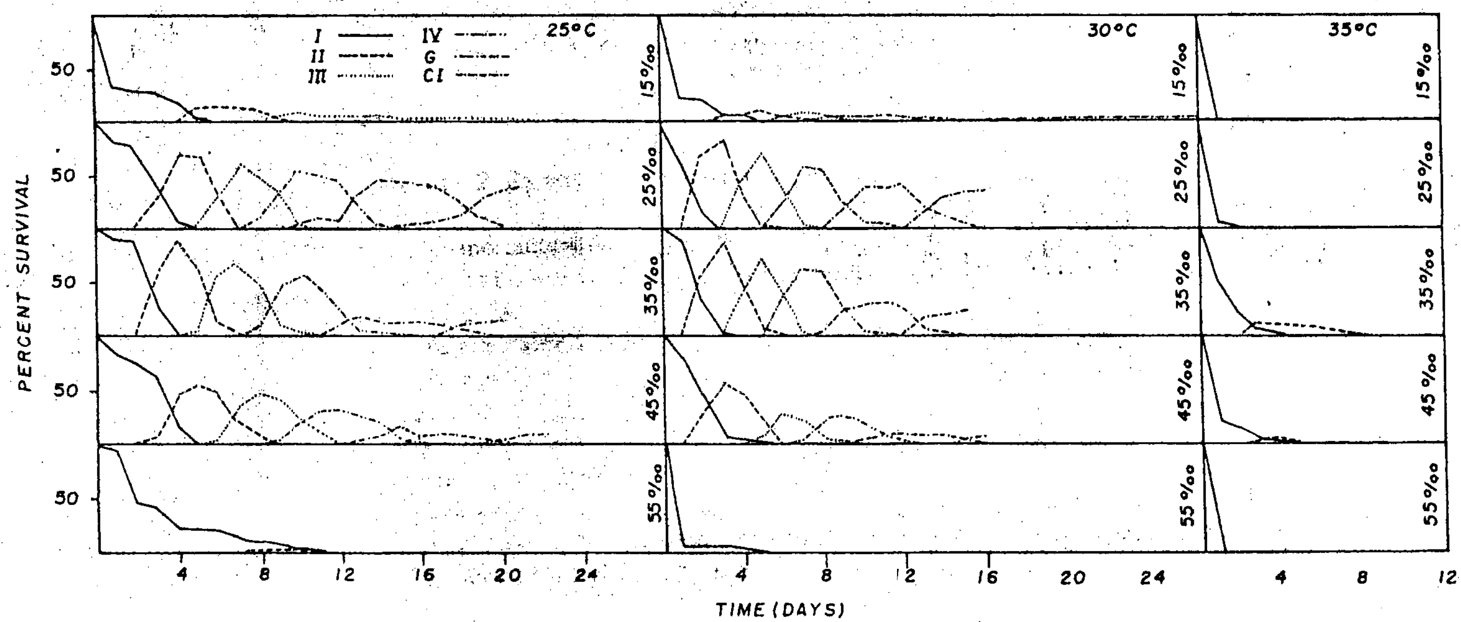


Fig. 2. The effect of salinity on survival and time to metamorphose of larval *Pagurus criniticornis*, at 25, 30 and 35 °C: I = first zoea; II = second zoea; III = third zoea; IV = fourth zoea; G = glaucothoe; CI = first crab.

23. Roundworms tolerate prolonged exposure to 200% seawater.

Species in four different genera were studied: *Axonolaimus, Cervonema, Daptonema, Sabatieria*. Two of the four genera experience no mortality, even after 48 h in 200% seawater. Roundworms like these will likely survive indefinitely in benthic substrates around the plant discharge experiencing the full "Average" – "Worst Case" scenario salinity range.

Salinity tolerance tests with benthic worms (nematodes) shows that all four species tolerate up to 8 h (and longer) exposure to 200% seawater. (Forster, 1998 J. Exp. Mar. Biol. Ecol. 224:109).

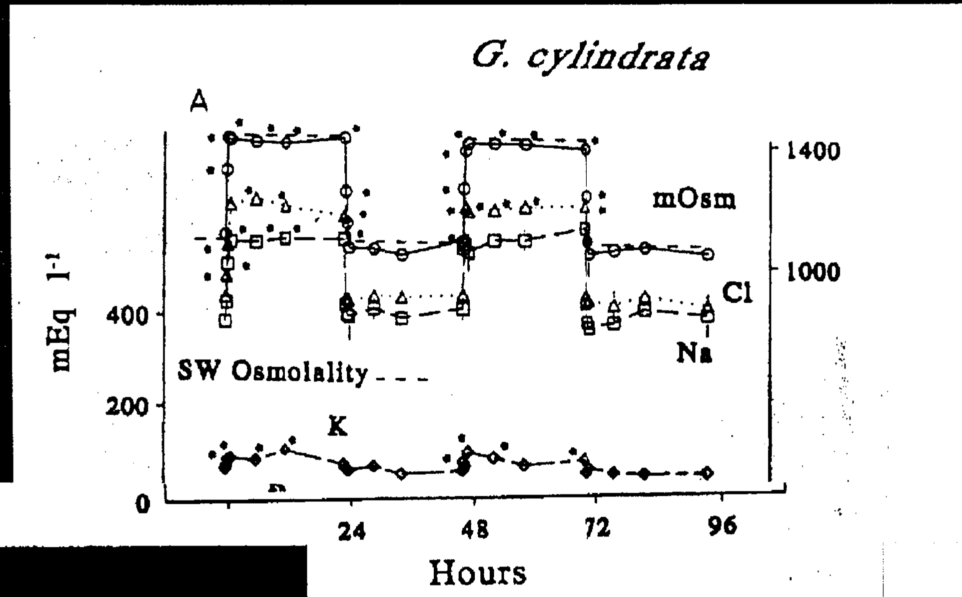
Table 2
Mortality (%) of *A. paraspinosus* (A.), *C. tenuicauda* (C.), *D. oxycerca* (D.) and *Sabatieria punctata* (S.) in the four ASW solutions at various time intervals

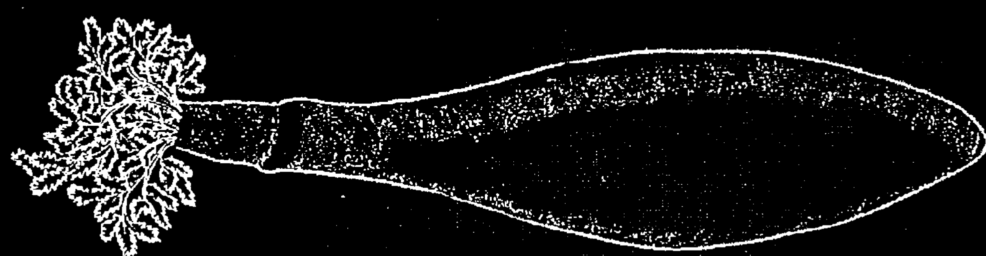
	Artificial Seawater Solutions															
	10%				50%				100%				200%			
	A.	C.	D.	S.	A.	C.	D.	S.	A.	C.	D.	S.	A.	C.	D.	S.
10 min	0	0	70	0	0	0	0	0	0	0	0	0	0	0	0	0
20 min	0	0	80	10	0	0	0	0	0	0	0	0	0	0	0	0
40 min	0	0	80	10	0	0	0	0	0	0	0	0	0	0	0	0
1 h	0	0	85	15	0	0	0	0	0	0	0	0	0	0	0	0
2 h	0	0	85	15	0	0	0	0	0	0	0	0	0	0	0	0
4 h	15	0	85	30	0	0	0	0	0	0	0	0	0	0	0	0
8 h	15	20	85	30	0	0	0	0	0	0	0	0	0	0	0	0
12 h	30	20	85	30	0	0	0	0	0	5	0	0	0	0	10	0
24 h	30	30	90	30	0	15	20	0	0	5	0	0	0	10	20	0
48 h	30	35	90	30	0	20	20	0	0	15	0	0	0	10	20	0

24. The peanut worm, *Goldfingia*, is an osmoconformer.

Graph shows how a “square-wave” salinity increase is followed by increases in tissue sodium and chloride ions, but not potassium ion.

Peanut worm (*Goldfingia*) is also an isosmotic osmo-conformer. (Ferraris et al., 1994, Mar. Biol.120:397)





25. The snapping shrimp, *Alpheus*, is also an osmoconformer.

Data set is nearly the same as in previous graph.

How a salinity increase affects the snapping shrimp's *(Alpheus)* tissue salt content (osmolarity).

(Ferraris et al., 1994, Mar. Biol.120:397)

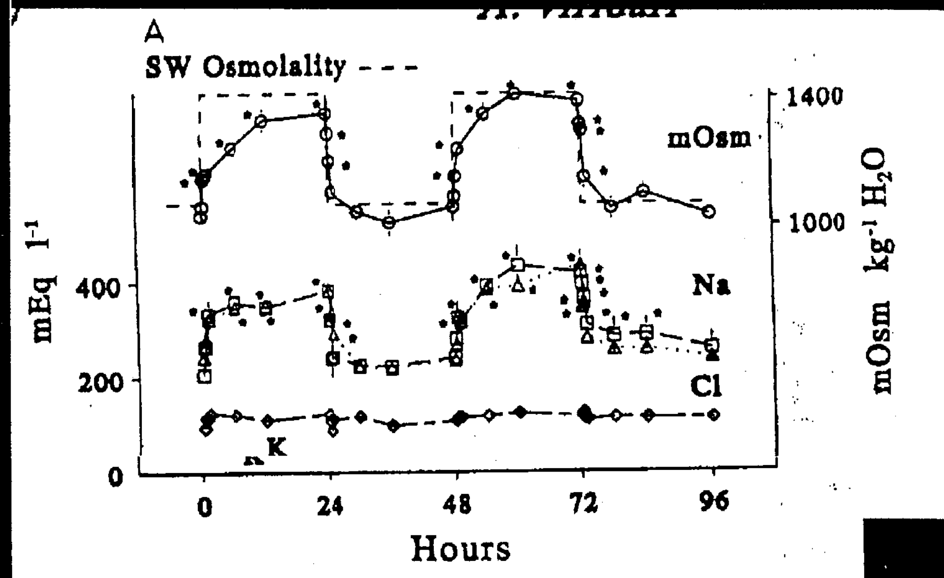


Figure 15-60. A pistol (or snapping) shrimp, *Alpheus*. (After Schmitt.)

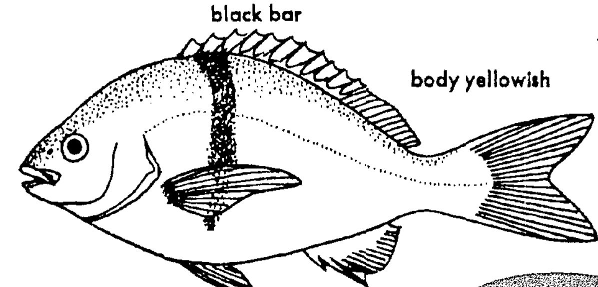
Snapping shrimp's internal salt level tracks the changes in seawater concentration because, like all marine invertebrates, it is "isosmotic" with seawater.

26. What about the fish?

All data presented to this point are for invertebrates, which are isosmotic with seawater and conform their tissue salt levels to changes in salinity. However, there are no salinity tolerance data for the invertebrates living near Huntington. What about the fishes? There have been several studies on fish species normally found in the area of the discharge. Before examining these, consider this short account for the Gulf of California croaker, bairdiella.

To this point, data about salinity effects on marine invertebrates has been presented.

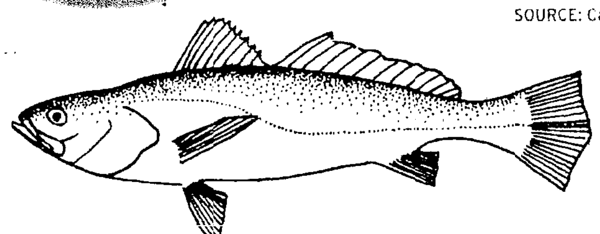
What about the Fish?



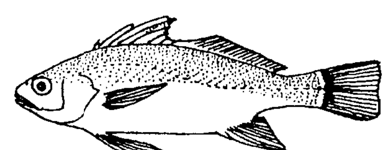
SARGO
Anisotremus davidsonii

Coming in on a high tide, the male approaches the female. Grunion's primal urges are so attuned to the lunar cycle that spawning "runs" can be predicted as much as a year in advance.

SOURCE: California Department of Fish and



Corvina

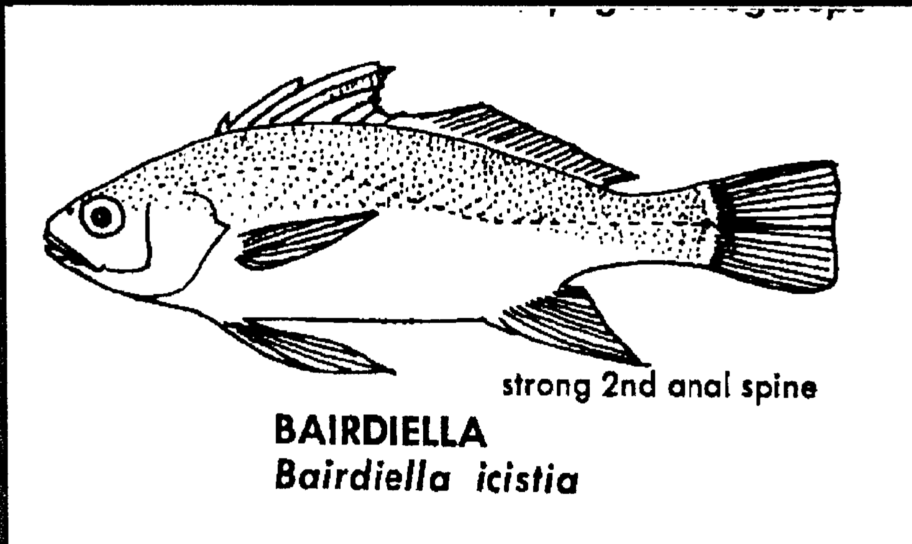


BAIRDIELLA
Bairdiella icistia

27. Bairdiella 1

Bairdiella icistia lives in the Gulf of California. (The common name of this fish, bairdiella, is the same as its binomial generic name, *Bairdiella*, which is both capitalized and italicized.) *Bairdiella* was introduced into the Salton Sea in the 1950s along with several other croakers and the sargo. (A number of species of fishes and invertebrates that live in southern California waters also live in the northern Gulf of California where salinities range from 36-39 ppt.) The bairdiella does not live in southern California waters, but its story, and that for a few other species, is very relevant to questions about salinity change. Studies cited in the figure show what was learned about salinity effects on the bairdiella when it was realized that the Salton Sea was getting too salty for fish there to survive.

The bairdiella (*Bairdiella icistia*) (the Gulf croaker).



For juveniles the optimal salinity for feeding and growth is 33-37 ppt.

Adverse effects seen at <29 and >45 ppt (Brocksen & Cole, 1972. JFRBCan. 29:399.)

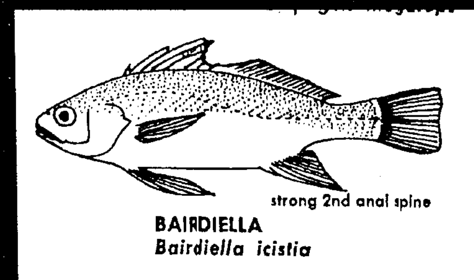
Salinities greater than 40 ppt adversely affect developing eggs and larvae (Lasker et al., 1972. CFG 58:58.)

28. Bairdiella 2

Studies of Dr. Bob May on *Bairdiella* help define the scientific approach needed for the RO discharge question. Need to consider combined temperature and salinity effects. May defined optimal salinity and temperature ranges.

Dr. Robert May did his Ph.D. at Scripps on the effects of temperature and salinity on *Bairdiella* development (May, 1972).

He studied all stages from fertilization to end of yolk sac. "Cannot consider temperature and salinity effects separately."



Range for successful development

Salinity 15-40 ppt

Temperature 20-30°C (68 -86°F)

Optimal combination of temperature and salinity for viable larvae development 26.6 ppt/24. 5°C (76.1°F)

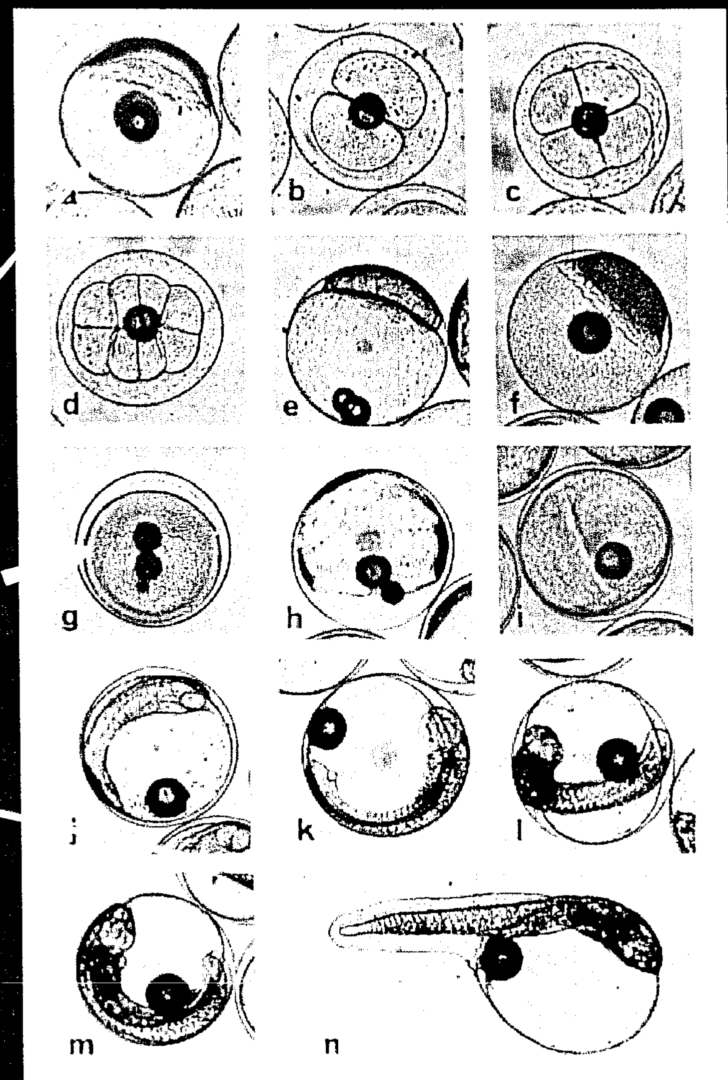
29. Bairdiella 3

May studied the complete development from fertilization to larval survival. He showed that salinity especially affected several stages, fertilization itself, gastrulation, and hatching.

Bairdiella

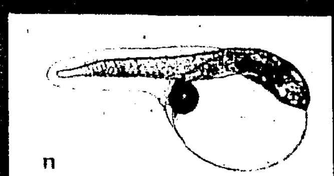
May found that the processes of fertilization, gastrulation, and hatch all quite subject to salinity effects.

Fertilization has to occur within ~ 30 sec (Haydock, 1971. USFish. Bull. U.S.69:157.)

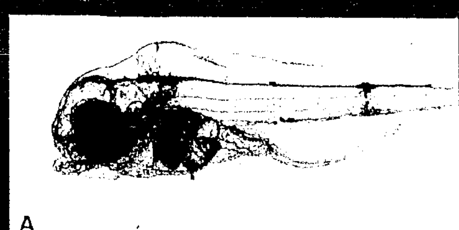


4 min. after fertilization

3 Gastrulation stages, 6,7, & 8 h



larvae 20 h. after fertilization

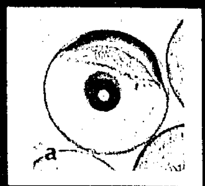


2 day old larvae

30. Bairdiella 4

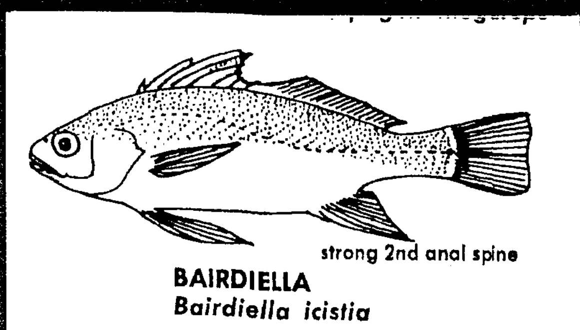
May learned a number of interesting facts about the susceptibility of different life stages to salinity. Although *Bairdiella* does not live along the southern California coastline, May's findings show that no stage of its development process would be affected by either the "Average" or the "Worst Case" scenarios projected for the power plant + RO discharge.

Bairdiella



Fertilization can occur in 45 ppt but development cannot proceed

Can tolerate 4-48 ppt for 24 h.
Can tolerate 5-45 ppt for 72 h

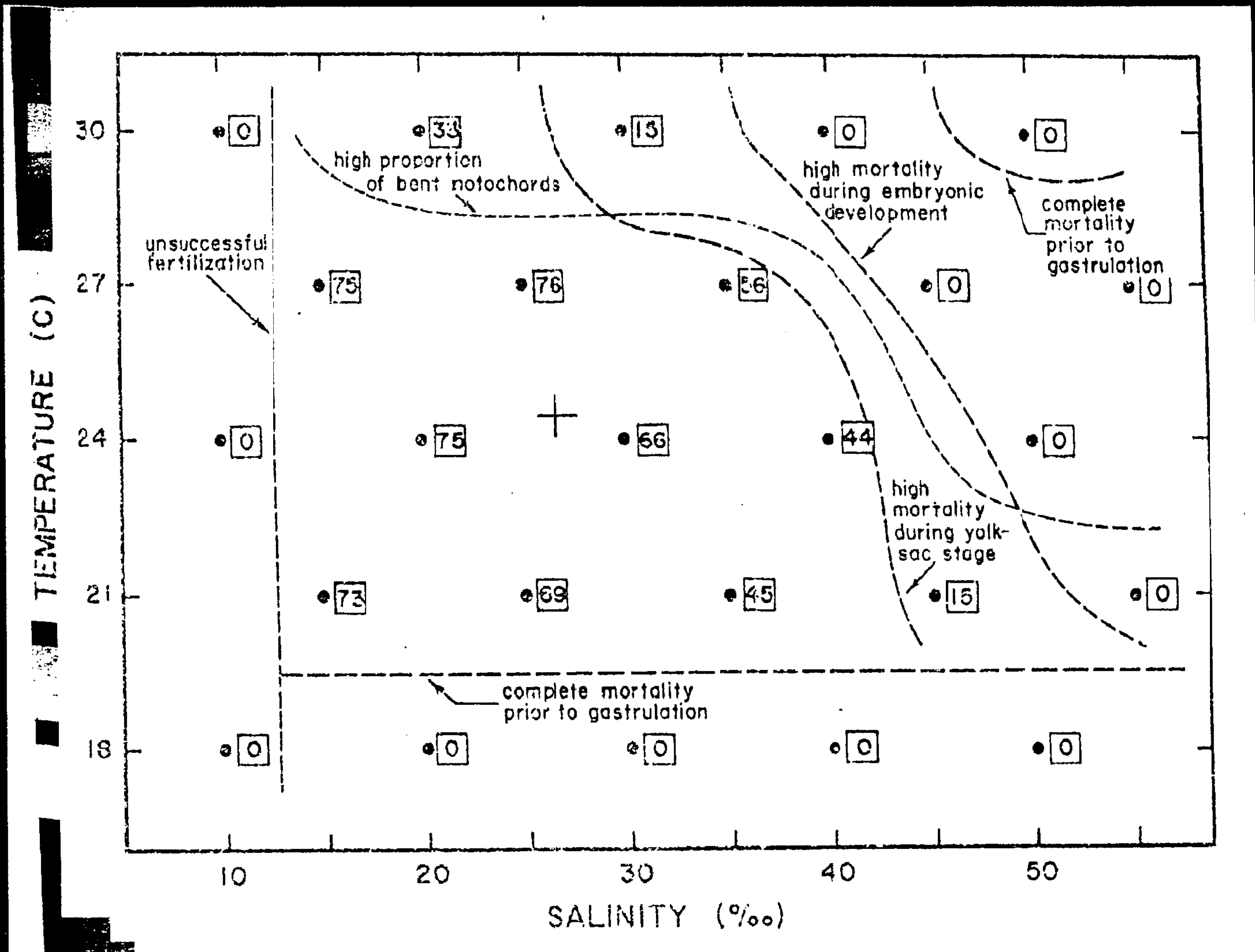


Adults and juveniles

Live in range from 0-45 ppt water. Can survive 52.5 ppt for 96 h and, if first acclimated, can live in 58 ppt for eight days.

31. Bairdiella 5

This fact is summarized in May's graph showing restrictive zones of combined temperature and salinity that limit the bairdiella's development.



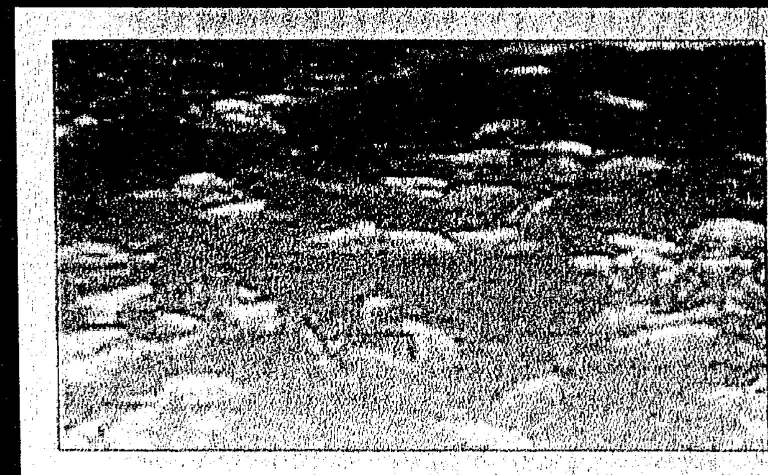
Combined temperature and salinity effects on early development of Bairdiella. (Dots are treatment combinations, numbers in squares the mean numbers of viable hatch.)

32. What about other fish?

The grunion tolerances exceed predicted conditions.

What about the other fish?

California Grunion, *Leuresthes tenuis*



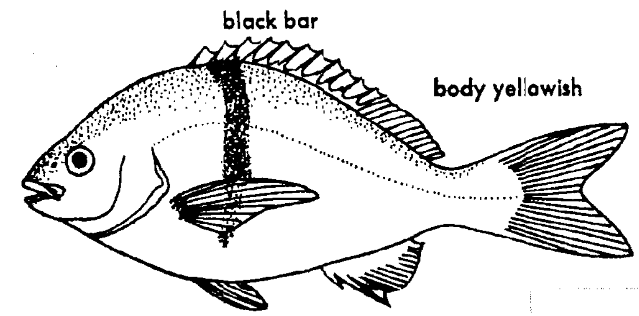
- Prolarvae (larvae with yolk sac, 4 days old) survive up to 41 ppt.

20-30 day larvae tolerate 38 up to ppt.

Adults tolerant of $\geq$ 37 ppt.

33. The sargo is similar to the bairdiella.

The sargo lives in southern California waters and also in the Gulf of California from where it was introduced into the Salton Sea. Studies on the sargo show tolerance ranges that far exceed predicted "Average" and "Worst case" conditions.



Sargo

Optimal salinity for juvenile feeding and growth is 33-37 ppt. (Brocksen & Cole, 1972. JFRBCan. 29:399.)

Adverse effects seen at <29 and >45 ppt. (Brocksen & Cole, 1972. JFRBCan. 29:399.)

Salinities greater than 40 ppt adversely affect developing eggs and larvae (Lasker et al., 1972. CFG 58:58.)

34. Summary I. Habitats A sandy, soft bottom habitat predominates throughout the area where the discharge will occur.

Thus, the spatial range over which organisms and communities similar to those found near the discharge have a wide distribution within the Southern California Bight. Also, all organisms living near the discharge have very broad geographic distributions. There are no "environmentally sensitive" habitats such as eel grass, rocky shores, kelp beds, or surf grass in the vicinity of the discharge.

Potential Marine Biological Effects of an RO Component in the AES Huntington Beach Cooling Discharge

I. The Habitat

- Sandy, soft bottom habitat, no rocky areas, no eel or surf grass or kelp beds

- Both the “Average” and “Worst case” scenarios result in moderate and very local effects.

- Spatial range of anomalous conditions caused by RO discharge is very limited relative to the geographical distributions of the organisms encountering it.

35. Summary II. Organisms-1

Pelagic vertebrates can avoid the discharge area by swimming if necessary and most vertebrates are highly insensitive to the small and short-term salinity effects predicted for the Huntington discharge area. Once carried into the discharge plume, drifters (eggs, larvae, plankton) will move down coast within it and experience the gradual return to ambient conditions. The buoyancy of these organisms may ultimately separate them from the slowly sinking salt wedge. In either case, most "drifters" have salinity tolerances that exceed both the extent and duration of the predicted exposure.

Potential Marine Biological Effects of an RO Component in the AES Huntington Beach Cooling Discharge
II. Resident Organisms-1

Pelagic

I. Vertebrates (fishes, turtles, mammals)

- Elevated salinity is moderate and areas are small and animals are unlikely to remain in contact long enough period to be affected.
- Mammals and turtles are "osmotically impermeable."
- Sensing such areas and either orienting to or avoiding them could occur.

II. Phyto- and zooplankton (including larvae) and macroinvertebrates (squid, jellies)

- Area of contact is small and residence time in area by drifting organisms will be short because of along shore current flow and rapid dilution.

36. Summary III. Organisms –2 Benthic effects

The "Average" case will have minimal effects because of rapid discharge dilution and a return to ambient conditions. The "Worst case" could have a greater effect, particularly as a permanent elevated benthic salinity area around the discharge. But, the "Worst case" has **A VERY LOW PROBABILITY OF OCCURRENCE AND THUS HAS LITTLE RELEVANCE TO THE QUESTION OF WHAT POSSIBLE BIOLOGICAL EFFECTS THERE WILL BE.**

Potential Marine Biological Effects of an RO Component in the AES Huntington Beach Cooling Discharge
III. Resident Organisms-2

Benthic Biota

I. Vertebrates (fishes)

- Avoidance behavior could occur, but most will easily tolerate level of salinity change associated with "Average" scenario.
- "Worst case" conditions could affect abundance and diversity near the discharge.

II. Invertebrates (polychaetes, nemerteans, echinoderms, mollusks, crustaceans)

- Most will be unaffected by "average" conditions.
- Some may use avoidance behavior or not settle in area.
- "Worst case" benthic salinity would likely affect some species.

Many of the species residing in the discharge area also occur in the upper Gulf of California where year-around salinities range from 35 to 38 ppt.